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Fort Belvoir, VA 22060-6201

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TECHNICAL REPORT

Radiation Internal Monitoring by In Vivo Scanning in Operation Tomodachi

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August 2013

Prepared by:

Operation Tomodachi Registry,
Dose Assessment and Recording Working Group

For:

Assistant Secretary of Defense for Health Affairs

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[1]Cassata, James; [2]McKenzie-Carter, Michael; [2]Case, David; [2]Chehata, Mondher; [3]Falo, Gerald

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[1]Uniformed Services University of Health Sciences, Bethesda, MD
[2]Science Applications International Corporation, McLean, VA
[3]U.S. Army Institute of Public Health, Aberdeen Proving Ground, MD

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9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Nuclear Technology Department, Attn: Dr. Paul Blake
Defense Threat Reduction Agency
8725 John J. Kingman Road, Mail Stop 6201
Fort Belvoir, VA 22060-6201

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14. ABSTRACT

Radioactive materials were released into the environment following the accident at the Fukushima Daiichi Nuclear Power Station following the earthquake and tsunami in Japan on March 11, 2011. Individuals in Japan affiliated with the Department of Defense (DOD) were exposed to these materials during Operation Tomodachi, and in response the DOD conducted the internal monitoring (IM) program described in this report. More than 7,900 DOD-affiliated individuals were internally monitored as part of this program from March 16 to August 31, 2011, at both CONUS and OCONUS locations. About 3% of those monitored had a measured activity greater than the minimum detectable activity (MDA). Those persons with measured activities greater than MDA had a maximum committed effective dose of 0.25 mSv (0.025 rem) and a maximum thyroid committed equivalent dose of 4.2 mSv (0.42 rem). In addition to descriptions of IM equipment, procedures, methodologies, and monitoring results, the report also includes discussions of the IM program's concept of operations, radiation safety directives, and quality assurance program.

15. SUBJECT TERMS
Operation Tomodachi, Radiation Dose, Department of Defense, Japan, Fukushima, Earthquake, Tsunami

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UNIT CONVERSION TABLE

U.S. customary units to and from international units of measurement*

U.S. Customary Units	Multiply by → / ← Divide by†		International Units
Length/Area/Volume			
inch (in)	2.54	$\times 10^{-2}$	meter (m)
foot (ft)	3.048	$\times 10^{-1}$	meter (m)
yard (yd)	9.144	$\times 10^{-1}$	meter (m)
mile (mi, international)	1.609 344	$\times 10^{3}$	meter (m)
mile (nmi, nautical, U.S.)	1.852	$\times 10^{3}$	meter (m)
barn (b)	1	$\times 10^{-28}$	square meter (m^2)
gallon (gal, U.S. liquid)	3.785 412	$\times 10^{-3}$	cubic meter (m^3)
cubic foot (ft^3)	2.831 685	$\times 10^{-2}$	cubic meter (m^3)
Mass/Density			
pound (lb)	4.535 924	$\times 10^{-1}$	kilogram (kg)
atomic mass unit (AMU)	1.660 539	$\times 10^{-27}$	kilogram (kg)
pound-mass per cubic foot (lb ft^{-3})	1.601 846	$\times 10^{1}$	kilogram per cubic meter (kg m^{-3})
Pound-force (lbf avoirdupois)	4.448 222		Newton (N)
Energy/Work/Power			
electronvolt (eV)	1.602 177	$\times 10^{-19}$	joule (J)
erg	1	$\times 10^{-7}$	joule (J)
kiloton (kT) (TNT equivalent)	4.184	$\times 10^{12}$	joule (J)
British thermal unit (Btu) (thermochemical)	1.054 350	$\times 10^{3}$	joule (J)
foot-pound-force (ft lbf)	1.355 818		joule (J)
calorie (cal) (thermochemical)	4.184		joule (J)
Pressure			
atmosphere (atm)	1.013 250	$\times 10^{5}$	pascal (Pa)
pound force per square inch (psi)	6.984 757	$\times 10^{3}$	pascal (Pa)
Temperature			
degree Fahrenheit (^oF)	$[T(^oF) - 32]/1.8$		degree Celsius (^oC)
degree Fahrenheit (^oF)	$[T(^oF) + 459.67]/1.8$		kelvin (K)
Radiation			
activity of radionuclides [curie (Ci)]	3.7	$\times 10^{10}$	per second (s^{-1}‡)
air exposure [roentgen (R)]	2.579 760	$\times 10^{-4}$	coulomb per kilogram (C kg^{-1})
absorbed dose (rad)	1	$\times 10^{-2}$	joule per kilogram (J kg^{-1}§)
equivalent and effective dose (rem)	1	$\times 10^{-2}$	joule per kilogram (J kg^{-1}**)

*Specific details regarding the implementation of SI units may be viewed at http://www.bipm.org/en/si/.

†Multiply the U.S. customary unit by the factor to get the international unit. Divide the international unit by the factor to get the U.S. customary unit.

‡The special name for the SI unit of the activity of a radionuclide is the becquerel (Bq). (1 Bq = 1 s^{-1}).

§The special name for the SI unit of absorbed dose is the gray (Gy). (1 Gy = 1 J kg^{-1}).

**The special name for the SI unit of equivalent and effective dose is the sievert (Sv). (1 Sv = 1 J kg^{-1}).

DTRA-TR-12-004: Radiation Internal Monitoring by In Vivo Scanning in Operation Tomodachi

Table of Contents

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List of Figures

List of Tables

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Executive Summary

This report describes the personnel monitoring program for internally-deposited radioactive material conducted by the Department of Defense (DOD) during Operation Tomodachi (OT). The purpose of OT was to provide humanitarian assistance and disaster relief to Japan following a devastating earthquake and associated tsunami on March 11, 2011. The operation was unique in that the Fukushima Daiichi Nuclear Power Station in Japan, damaged by the tsunami, suffered a radiological release that potentially affected 70,000 DOD-affiliated individuals on or around the four main islands of Japan (Hokkaido, Honshu, Shikoku, and Kyushu). The primary objectives of the OT internal monitoring (IM) program were to provide potentially-affected individuals and military commanders with prompt assessments of any intakes of radioactive materials, to more fully characterize individual internal exposures, and to identify DOD-affiliated individuals who possibly had an increased risk of adverse health effects.

The National Council on Radiation Protection and Measurements (NCRP) performed a timely, thorough, and scientifically rigorous peer review of draft versions of this report, providing invaluable technical contributions that were incorporated into the final version of this report. The NCRP review was conducted by Scientific Committee SC 6-8, consisting of four experts in the field of dose reconstruction, internal monitoring, and occupational surveillance programs. Assisting with the NCRP review were two certified health physicists from two different private consulting firms, with over 20-years each of operational experience with military radiological controls and instruments.

The OT IM program was conducted from March 16, 2001 through August 31, 2011. During the program, 8,378 IM measurements were performed on approximately 7,947 DOD-affiliated individuals. Monitoring was performed in three phases: a continental United States (CONUS) phase, an outside the continental United States (OCONUS) phase, and an OCONUS open availability phase. About 3 percent of those measurements had an activity greater than the minimum detectable activity (MDA). The measured activities that were greater than the MDA resulted in a maximum whole body committed effective dose of 0.25 mSv (0.025 rem) and a maximum committed equivalent dose to the thyroid of 4.2 mSv (0.42 rem). Table ES-1 summarizes the results for the three monitoring phases.

About 11 percent of the monitored individuals were internally monitored in the United States using existing equipment at U.S. Naval shipyards before the program became operational in Japan. About 87 percent of the individuals were monitored in or around Japan using both fixed and portable IM systems. The remaining two percent were monitored in Japan as part of a voluntary self-referral or open availability period, which included DOD civilian employees and family members, using both fixed and portable systems.

The IM program was formalized using a concept of operations, written directives, and other operational instructions described in this report. This monitoring was performed by highly trained site managers at 44 unique locations (both afloat and ashore). Each site manager was responsible for the technical oversight of all work and for the technical performance of all personnel performing internal monitoring at their site. The use of carefully prepared scripts was standardized to explain the procedure (pre-scan) and the significance of the results (post-scan) to the monitored individual.

Table ES-1. Characterization of IM doses greater than MDA for three IM phases

IM Phase	Dose Statistic	Committed Effective Dose (mSv [rem])*	Committed Equivalent Dose to the Thyroid (mSv [rem])*	Dates (2011) of Measurements > MDA	
				Earliest Date	Latest Date
CONUS†, Mar 16– May 19, 2011	Maximum	0.05 [0.005]	0.77 [0.077]	Mar 16	Apr 11
	Mean	0.02 [0.002]	0.34 [0.034]		
	Minimum	0.01 [0.001]	0.09 [0.009]		
OCONUS‡, Operational, Apr 14– Aug 31, 2011	Maximum	0.25 [0.025]	4.2 [0.42]	Apr 14	Aug 10
	Mean	0.06 [0.006]	1.0 [0.10]		
	Minimum	0.02 [0.002]	0.29 [0.029]		
OCONUS, Open Availability, Jul 26– Aug 31, 2011	Maximum	N/A§	N/A	N/A	N/A
	Mean				
	Minimum				

* Committed doses do not include dose contributions from external radiation sources. These dose values are only due to radionuclides taken into the body.

† CONUS indicates "Continental United States."

‡ OCONUS indicates "Outside CONUS."

§ N/A indicates "Not Applicable", i.e., there were no IM results (activities) greater than the MDA.

Committed doses were calculated with the assistance of an automated spreadsheet, called the Internal Activity and Dose Calculation Tool. Daily internet uploads of doses and datasheets were accomplished from each site to a centralized data portal. Each day all new files were downloaded and reviewed at a central technical management center for evaluation and feedback. A comprehensive quality assurance program was implemented at the onset of the OT IM program, and was rigorously executed through its conclusion.

Results of the OT IM program validate the conclusion that the internal radiation doses of the 70,000 DOD-affiliated individuals of concern were low and were well below levels that would require any intervention under U.S. radiological protection guidance. The highest effective dose calculated for any individual is 0.25 mSv (0.025 rem), and at effective doses less than about 50 to 100 mSv (5 to 10 rem), "risks of health effects are either too small to be observed or are nonexistent" (HPS, 2010).

In the future, individual dose assessments will not normally be necessary for this population. This is because conservative population dose estimates are small, as demonstrated in the OT dose estimates reported in Cassata et al. (2012). However, there may be some individuals for whom a future individual dose assessment may be necessary. A full assessment of an individual's radiation dose will require an evaluation of both external and internal sources of dose. The IM results described in this report should be an integral part of such an assessment.

Section 1.

Introduction

1.1 Purpose of this Report

This report describes the Department of Defense (DOD) Operation Tomodachi (OT) personnel monitoring program for internally-deposited radioactive material, also known as the radiation internal monitoring (IM) program. The program involved the use of fixed, full-body scanners and portable instruments to assess the amount of radioactive material that may have been deposited in the bodies of DOD-affiliated individuals. This report refers to this program as the OT Radiation Internal Monitoring by In Vivo Scanning (RIMIS) program, and documents the approach, methods, technical basis, results, and the validation of the OT RIMIS program.

This report supplements *Radiation Dose Assessment for Shore-Based Individuals in Operation Tomodachi, Revision 1* (Cassata et al., 2012), and is one of a series of DOD reports undertaken by the OT Registry's Dose Assessment and Recording Working Group (DARWG) to assess radiation doses to DOD-affiliated individuals or to characterize the radiological environment at J-Village (a sports complex about 20 km (12.5 mi) from the Fukushima Daiichi Nuclear Power Station (FDNPS) and used as a staging area for visitors to the Fukushima area). These reports include:

- Radiation Dose Assessments for Shore-Based Individuals in Operation Tomodachi, Revision 1 (DTRA-TR-12-001 [R1]).
- Probabilistic Analysis of Radiation Doses for Shore-Based Individuals in Operation Tomodachi (DTRA-TR-12-002).
- Radiation Dose for Embryo, Fetus and Nursing Infants from Operation Tomodachi (DTRA-TR-12-017).
- Radiation Doses for Fleet-Based Individuals in Operation Tomodachi (DTRA-TR-12-041).
- Characterization of the Radiological Environment at J-Village during Operation Tomodachi (DTRA-TR-12-045).
- Comparison of Radiation Dose Studies of the 2011 Fukushima Nuclear Accident Prepared by the World Health Organization and the U.S. Department of Defense (DTRA-TR-12-048).
- Standard Methods and Standard Operating Procedures for Responding to Operation Tomodachi Individual Dose Assessments and Responding to VA Radiogenic Disease Compensation Claims (AIPH Standard Methods/Standard Operating Procedures).

1.2 OT RIMIS Program Objectives

The United States Pacific Command (USPACOM) Surgeon's Office implemented the OT RIMIS program to provide measurements to assess the intakes of radioactive material released from the FDNPS by DOD-affiliated individuals. The objectives of the OT RIMIS program were:

- To provide individuals with an assessment of their intakes of radioactive materials released from the FDNPS during or just after the time they were working or living near the release.
- To provide operational commanders with timely assessments of intakes of radioactive material by persons under their command.
- To document individual internal monitoring results in support of future dose investigations and estimates.
- To operate the program, from inception through conclusion, with numerous quality assurance and quality control elements so that the internal monitoring results would be reliable and technically defensible.

1.3 Background Information

Significant releases of radioactive material from the FDNPS followed the March 11, 2011[1] earthquake and subsequent tsunami off the east coast of Japan. It is estimated that about 70,000 DOD-affiliated individuals were working and/or living at locations in and around Japan and who were potentially exposed to small amounts of the released radioactive material or radiation emitted by the material. About 53,000 individuals were at shore-based locations and about 17,000 individuals were afloat, participated in air crew operations or visited J-Village, a staging location for Japanese personnel responding to the accident.

Implementation of IM in the OT RIMIS Program involved adaptation of routine capabilities to the conditions encountered under emergency response and presented major challenges related to the availability of IM equipment, the large number of potential persons to be evaluated, and to the time sensitivity of measurements. Shore-based DOD IM equipment in Japan was initially very limited. In addition, thousands of persons could be identified as candidates for IM, and the measurements were time sensitive because of radioactive decay and biological elimination of any potentially inhaled or ingested radioactive material.

A team composed of four senior military health physicists from the U.S. Air Force, U.S. Army, and U.S. Navy was sent to USPACOM to develop the OT RIMIS procedures and manage the establishment of the OT RIMIS program. One of the Navy's health physicists (Commander James Cassata) was selected because of his three-year participation on Scientific Committee 4-2 of the National Council on Radiation Protection and Measurements (NCRP) whose purpose was to study and provide guidance on large scale population monitoring after a radiological event. Many of the key concepts incorporated into the OT RIMIS program were formally addressed by this committee and are discussed in the committee's final published report (NCRP, 2010). These key concepts and actions include coordination with the incident command system, incorporation of radiological triage and screening guidance, and rapid determination of personnel internal contamination using direct (in vivo) screening with portable instruments. Commander Cassata's experience with the NCRP committee had a direct influence on the OT RIMIS program, including the decision to use both fixed scanners and portable instruments to perform IM measurements. The fixed scanners were Canberra ACCUSCAN II™ and FASTSCAN™ systems and the portable instruments comprised an Eberline E-600 survey meter and a SPA-3 scintillation detector probe, hereafter referred to as an E-600/SPA-3 pair.

[1] Dates and times given in this report are local time (typically Japan Standard Time) unless otherwise indicated.

The DOD inventory of operable, portable instrumentation was large enough to rapidly monitor large numbers of people. This had an added advantage of being able to readily distribute the instruments to perform measurements at remote locations (ships and humanitarian relief sites), thereby avoiding disruption of the overall OT humanitarian relief mission. Twenty-five (25) portable E-600/SPA-3 instrument pairs were used in support of OT RIMIS operations. There were three fixed scanners available for IM monitoring in Japan located at U.S. Naval Hospital, Okinawa, Yokosuka Naval Base (NB), and Atsugi Naval Air Facility (NAF). These units are large, heavy (due to the radiation shielding), and much more costly than the portable instruments.

Whenever operationally possible, all individuals with an IM portable instrument measurement result above the MDA were also measured on one of the fixed scanners. This was accomplished for two reasons: first, to confirm the portable instrument measurement, and second, to have a set of paired measurements that could be used to determine IM calibration factors for the portable instruments. Whenever a confirmatory, fixed scanner measurement wasn't operationally possible, a second portable instrument measurement was performed to confirm the first IM measurement.

Internal monitoring during Operation Tomodachi occurred during three phases:

- Continental United States (CONUS) from March 16–May 19, 2011,
- Outside of CONUS (OCONUS) for operational forces from April 14–August 31, 2011, and
- OCONUS open availability from July 26–August 31, 2011.

Since there were limited shore-based DOD IM fixed scanners available in Japan immediately following the March 11, 2011, earthquake, individuals with potential intakes who were working at the Yokosuka NB, received full body IM scans at U.S. Navy facilities on the west coast of the United States. Within 30 days of the earthquake, 436 individuals were monitored in CONUS. Eventually 944 persons were monitored in CONUS during a period of about 118 days starting on March 16, 2011. Overall there were 104 measured activities of 37–296 Bq (1 to 8 nCi) of I-131, all measured during the first 53 days of CONUS monitoring, resulting in estimated committed equivalent doses to the thyroid ranging from 0.09 to 0.77 mSv (0.009–0.077 rem).

OCONUS measurements for operational forces began when initial DOD IM capabilities were established in Japan at Atsugi NAF on April 12, 2011, with a fixed scanner and portable instruments. Program elements accomplished during the 32-day period between the earthquake and the start of IM in Japan included the concept of operations, acquisition of equipment, transportation of thousands of pounds of equipment to Japan, standard operating procedures, installation and calibration of equipment, and training equipment operators.

The personnel monitored at Atsugi NAF on April 12 and 13, 2011, had to be re-monitored because small amounts of contamination found on their clothing confounded the results. Therefore, the first acceptable OT RIMIS measurements OCONUS occurred on April 14, 2011. The OCONUS operational IM studies totaled 7,277 individual measurements during a period of about 140 days of monitoring. Two shore-based sites, at Yokosuka NB and at the U.S. Naval Hospital, Okinawa, were established with fixed scanning systems during the several weeks after the startup at Atsugi NAF.

The third phase of OT RIMIS measurements comprised an open availability or voluntary phase, which allowed any individual to ask to be internally monitored. The open availability phase was conducted from July 26 to August 31, 2011 (37 days), with the final measurement completed on August 29, 2011. The 155 individual measurements made during this phase were conducted at Atsugi NAF, and included military personnel, civilian employees, contractors, and dependents, including infants and children.

A total of 8,378 measurements[2] were made on 7,947 individuals during the CONUS, OCONUS operational, and OCONUS open availability phases of the OT RIMIS. The number of individuals is less than the total number of measurements because more than one valid measurement was made on some individuals.

1.4 Radiological Quantities and Units

The radiation doses received by an individual are generally characterized either in terms of effect on the entire body or effect on individual body organs or tissues. The dose from external sources is generally characterized as the dose to the whole body and is expressed as effective dose. Doses from internal sources are characterized by the dose to individual organs or tissues, and depend on the amount of radioactive material taken into the body and on the distribution throughout the body to various organs and tissues. These internal doses are generally characterized either as a "committed effective dose" to represent the contribution to overall effect on the body as a whole, or as an "equivalent dose" to a specific organ or tissue. The quantities calculated in this report for IM results are the committed effective dose and committed equivalent dose to the thyroid as presented in International Commission on Radiological Protection (ICRP) Publication 60 (ICRP, 1991). The ICRP Publication 60 series of reports (e.g., ICRP, 1991; 1994a; 1994b; 1995; 2012) were used because they reflect more refined dosimetry models than the previous ICRP recommendations (e.g., ICRP Publication 30 [ICRP, 1979]). Furthermore, specific values such as dose coefficients (DCs) from the ICRP Publication 60 series were the most up-to-date available from the ICRP or elsewhere (ICRP, 2012), and were accepted and used internationally. Dose coefficients based on ICRP Publication 60 were readily available (e.g., ICRP, 2001; 2012), and had not yet been replaced by DCs based on the more recent recommendations of the ICRP (ICRP, 2007a; 2012). Table 1 lists radiation dosimetry terms and quantities. Although external dose is mentioned in Table 1, the IM procedures do not assess dose from exposure to external sources of radiation.

The units used in this report are a mixture of traditional and international[3] radiological units. Generally, measured quantities and calculated quantities were in traditional units, whereas tabulated quantities in the literature were in international units. Unit conversion factors were used where necessary.

[2] The number of individual measurements cited here was previously thought to represent the number of individuals on whom measurements were made. Some publications may incorrectly indicate that it is the number of individuals.

[3] International units in this report are based on the International Bureau of Weights and Measures publication *Le Système International d' Unités*, commonly abbreviated "SI" .

Table 1. Radiation dose terms

Radiation Dose Term	Symbol and Definition	Comments
Absorbed (Organ) Dose	D_T	As used in this report, the absorbed dose is the amount of energy deposited in an organ or tissue divided by the mass of the organ or tissue. The SI unit for absorbed dose is J kg^{-1} and is given the special name gray (Gy). The conventional unit for absorbed dose used in the United States is the rad; 1 rad = 0.01 Gy.
Radiation Weighting Factor	w_R	The radiation weighting factor is a unitless, multiplicative factor applied to the absorbed dose to account for probability of the type and energy of the radiation to cause stochastic effects (*e.g.* cancer).
Equivalent Dose	$H_T = \sum_R w_R D_{T,R}$	The equivalent dose to a tissue or organ, *T*, from radiation, *R*, is the absorbed dose multiplied by the radiation weighting factor. The radiation weighting factor is unitless; therefore the units of equivalent dose are the same as for absorbed dose, J kg^{-1}. The special name for the SI unit of equivalent dose is the sievert (Sv). The conventional unit for equivalent dose used in the United States is the rem; 1 rem = 0.01 Sv.
Tissue Weighting Factor	w_T	The tissue weighting factor for a particular organ or tissue is used to account for the "relative contribution of that organ or tissue to the total detriment (*e.g.,* cancer) due to these effects resulting from a uniform irradiation of the whole body." (ICRP, 1991) The values for w_T are based on a "reference population of equal numbers of both sexes and a wide range of ages." (ICRP, 1991) The values are independent of radiation type and energy and apply to workers and the general population of both sexes. (ICRP, 1991) The sum of the tissue weighting factors is equal to one (1.0) to ensure "that a uniform equivalent dose over the whole body should give an effective dose [See next entry.] numerically equal to that uniform equivalent dose." (ICRP, 1991)

Table 1. Radiation dose terms (cont.)

Radiation Dose Term	Symbol and Definition	Comments
Effective Dose	$E = \sum_T w_T H_T$ or $E = \sum_T w_T \sum_R w_R D_{T,R}$ $= \sum_T w_T \sum_R H_{T,R}$	The effective dose is the sum of the tissue weighted equivalent doses to all the tissues and organs as presented in ICRP Publication 60 (ICRP, 1991) and used in the ICRP databases of DCs (ICRP 2001, 2003, 2007b). The special name for the SI unit, J kg^{-1}, of effective dose is the sievert (Sv). The conventional unit for effective dose used in the U.S. is the rem; 1 rem = 0.01 Sv. Alternately, the effective dose is the doubly weighted sum (radiation and tissue weighting factors) of the absorbed organ doses. The w_T values used in RIMIS calculation were based on ICRP Publication 71 (ICRP, 1995).
Committed Equivalent Dose	$H_{T,\tau}$ or $H_T(\tau)$	The committed equivalent dose is the equivalent dose to a tissue or organ from internally deposited radionuclides during the period τ following an intake. For workers a period of 50 years is used; for members of the public the period is 50 years and for children the period is from exposure to age 70.
Total Thyroid Equivalent Dose	H_{Thy}	The total thyroid equivalent dose is equal to the sum of external radiation dose (equivalent dose to the whole body) and internal radiation dose (committed equivalent dose to the thyroid). In this report, the total thyroid equivalent dose is called the thyroid dose.
Committed Effective Dose	$E(\tau)$	The committed effective dose is the effective dose to the body from internally deposited radionuclides during the period τ following an intake. For workers a period of 50 years is used; for members of the public the period is 50 years and for children the period is from exposure to age 70.
Total Effective Dose	TED	The TED is used most often to demonstrate compliance with standards. The TED is calculated by summing the external radiation dose (e.g., E) and the committed effective dose. TED is not used in this report.

1.5 Policy and Procedure Documents Governing Internal Monitoring Operations

Several documents were critical to the selection of individuals to be monitored and the procedures for IM at locations where both fixed and portable instrumentation were used (Table 2). These documents are summarized below Table 2.

Table 2. Monitoring locations and measurement systems used in OT RIMIS program

Location* (44)	
CONUS, Land-Based Fixed Scanner† (6)	
Bangor (Kitsap NB), WA Naval Dosimetry Center, Bethesda, MD Norfolk Naval Shipyard, VA	North Island NAS, CA Point Loma NB, CA Puget Sound Naval Shipyard, WA
OCONUS, Land-Based Fixed Scanner and Portable Instrument (3)	
Atsugi NAF; Japan U.S. Naval Hospital, Okinawa	Yokosuka NB, Japan
OCONUS, Land-Based Portable Instrument (17)	
Camp Zama, Japan Iwakuni MCAS, Japan Matsushima AB, Japan Misawa AB, Japan Sasebo NB, Japan Yokota AB, Japan	Cities of Ikego, Ishinomaki, Makashima, Miyaka, Ofunato, Oshima, Taegu, Yamagata Eielson AFB, AK Futenma MCAS, Japan Pohang MEC, Republic of Korea
OCONUS, Ship-Based Portable Instrument (18)	
USS Blue Ridge (LCC-19) USS George Washington (CVN-73) USS Cowpens (CG-63) USS Shiloh (CG-67) USS Curtis Wilbur (DDG-54) USS John S. McCain (DDG-56) USS Fitzgerald (DDG-62) USS Lassen (DDG-82) USS McCampbell (DDG-85)	USS Mustin (DDG-89) USS Ronald Reagan (CVN-76) USS Chancellorsville (CG-62) USS Preble (DDG-88) USS Essex (LHD-2) USS Germantown (LSD-42) USS Tortuga (LSD-46) USNS Bridge (T-AOE-10) USS Frank Cable (AS-40)

* Military locations and ship hull numbers may be abbreviated (see Section entitled "Abbreviations, Acronyms, and Unit Symbols").

† Fixed Scanner = ACCUSCAN II or FASTSCAN system; Portable Instrument = E-600/SPA-3 system.

1. Concept of Operations for Internal Monitoring Navy Personnel Participating in OT (Original April 8, 2011): this document outlines roles, responsibilities and procedures for persons and facilities involved with internal monitoring of DOD personnel for internal radionuclide deposition as a result of participating in OT. There were several revisions to this document, and the final version used was dated May 17, 2011 (see Appendix A).
2. Health Physicist Directive (HPD) for Internally Monitoring Personnel Participating in Operation Tomodachi (Original Version 1.0/April 11, 2011): this document provides the overall instructions for the performance of IM at the three sites using both Canberra fixed scanners and portable E-600/SPA-3 instruments and for the numerous remote sites where

only portable instruments were used. There were several revisions to this document. The final HPD was the version dated July 22, 2011 (see Appendix B).

3. Internal Monitoring Procedure for Use with the E-600/SPA-3–Knolls Atomic Power Laboratory: This document prescribes the IM procedures using the portable E-600/SPA-3 survey meter and probe. It includes specifications on count times, background counts, performance of IM on thyroid and chest/back, signatures, and reviews. It also includes data sheets for background counts and personnel monitored. There were several revisions to this document (see Appendix D).
4. ACCUSCAN II Procedures Document: These procedures include the set-up, calibration, and daily operations of the Canberra ACCUSCAN II full body scanner (PSNS, 2012a; PSNS, 2012b). Canberra scanners were operated and managed by trained Naval Nuclear Propulsion Program (NNPP) shipyard workers. One ACCUSCAN II system was used at Atsugi NAF.
5. FASTSCAN Procedures Document: These procedures include the set-up, calibration, and daily operations of the Canberra FASTSCAN full body scanner (PSNS, 2011; PSNS 2012c). Canberra scanners were operated and managed by trained NNPP shipyard workers. One FASTSCAN system was used at Yokosuka NB and another one was used at U.S. Naval Hospital, Okinawa.
6. Internal Monitoring Daily Quality Assurance (QA) Sheet: This document was part of the quality assurance program, and was used by individual IM site managers (SMs) who were assigned, trained, and solely responsible for all IM operations at a particular location. These sheets were used to summarize results each day, which were then reported back to USPACOM for overall operations monitoring. The concept of a single responsible SM at each location where IM was performed was a key part of the design of the quality assurance system (see Section 6). Other parts of the quality assurance system included detailed procedures, requirements for compliance, strong central management oversight in Japan and at USPACOM in Hawaii, highly trained individuals performing IM, daily review of data, redundant measurements for those indicating a measureable intake, and redundant daily background checks for each instrument.
7. Procedure for Submission of Internal Monitoring Summary Forms into the Deployment Occupational & Environmental Health Surveillance (DOEHS) Data Portal (Army Public Health Command): This document provided the instructions for the daily uploading of data sheets to DOEHS, which were then downloaded and reviewed at USPACOM.
8. Guide for IM Appointment Schedulers: This document provided information and guidance for personnel involved with the appointment scheduling for family members as part of the open availability phase.
9. Question and Answers Document: USPACOM June 16, 2011 (See Appendix I)

1.6 Criteria for Selection of Individuals for Internal Monitoring

1.6.1. Internal Monitoring in CONUS Phase

DOD workers at the Yokosuka NB with the potential for internal intakes of radioactive material were sent to established DOD IM facilities in CONUS during the period of March 16

through April 11, 2011. A total of 944 persons were internally monitored during this period, representing about 11 percent of the total number of individuals who underwent IM in the OT RIMIS program. After establishing the OT RIMIS program in Japan on April 11, 2011, it was no longer necessary to perform OT RIMIS IM in CONUS.

On March 21, 2011, the U.S. Navy Bureau of Medicine and Surgery (BUMED) issued the BUMEDNOTE provided in Appendix G-1 to announce the implementation of a voluntary radiation risk assessment and guidance form, NAVMED 6470/16. The purpose of this form was to document environmental exposures and possible health effects for the DOD-affiliated population. The information recorded on the NAVMED 6470/16 was collected and archived at the Naval Dosimetry Center (NDC), Bethesda, MD. DARWG's review of the archived information found 1,993 submitted forms with the following distribution among individual's classifications: Active Duty Personnel (715), Civilian Employees (1,161), Dependents (114), and Retired Personnel (3).

1.6.2. Internal Monitoring OCONUS Phase

1.6.2.1 Initial Criteria for IM

Internal monitoring OCONUS was conducted according to an approved Concept of Operations. Initial IM conducted OCONUS was performed in accordance with the Concept of Operations dated April 8, 2011 (see Appendix A). The sampling plan used to determine the selection of individuals during this initial period of IM is shown in Table 3.

Table 3. Internal monitoring sampling and equipment criteria

Sampling Group and Population	Sampling Size	Monitoring System*	
		Fixed	Portable
Group 1: Active Duty personnel operating within the Sendai area	100%	X	X
Group 2: Aviators (i.e., pilots and aircrews) that flew through plumes	100%	X†	X
Group 3: Aviation support personnel; aircraft/ship decontamination teams	100%	X†	X
Group 4: Ship's crew (including nuclear trained personnel)	The lesser of 100 individuals or 10% of the crew	X†	X
Group 5: Shore activity personnel	The lesser of 100 individuals or 10% of assigned personnel	X†	X
Group 6: NNPP Personnel‡	Per NNPP requirements	X	X‡
Group 7: Others§	Per JSF-J requirements	X†	X

* See Section 2.
† Selected individuals with E-600/SPA-3 readings above/below the MDA for equipment intercomparison.
‡ As deemed appropriate by the Naval Nuclear Propulsion Program.
§ As deemed appropriate by Joint Support Forces-Japan, with USPACOM concurrence.

1.6.2.2 Revised Criteria for IM

The USPACOM directive issued on April 20, 2011, updated and further implemented the Concept of Operations of April 8, 2011, and superseded guidance from the Commander, Joint Support Forces Japan, dated April 16, 2011. The directive contained specific direction to Service commands to identify personnel with higher potential for internal contamination. Personnel were to be identified and prioritized according to the following six categories, listed in order of decreasing concern (see Appendix C for additional details of this directive):

- Military personnel and DOD civilian employees who had been within the "warm" or "hot" zones surrounding FDNPS after March 14 or April 14, 2011, respectively (see Appendix C for zone definitions)
- All personnel with documented radioactive skin contamination
- Military personnel and DOD civilian employees who flew missions through known plumes
- Military personnel and DOD civilian employees who were involved in decontamination activities
- Military personnel and DOD civilian employees supporting ship crews who operated from ships or aircraft in either the warm or hot zone
- Other personnel and DOD civilian employees deemed to be appropriate for monitoring

1.6.3. OCONUS Open Availability Phase

The USPACOM Surgeon's Office determined that IM should be offered on a voluntary self-referral or so-called "open availability" basis to all DOD-affiliated adults, children, and infants who were working or living in Japan following the March 11, 2011, earthquake. The open availability period ran from July 26 through August 31, 2011. This was done as a public service and to help alleviate individual's concerns that they or family members may have been exposed at levels that could result in a significant long term health risk. Trained DOD personnel, including a risk communicator, made onsite visits to the major bases in the Kanto Plain region of Japan and held open house meetings to talk about the open availability phase that would offer IM at Atsugi NAF for anyone requesting monitoring. During the open house meetings, attendees were given information, which included the following USPACOM prepared statements.

- "Since the March 11 earthquake and tsunami, the DOD, along with the US Department of Energy, the U.S. Nuclear Regulatory Commission and the Government of Japan have been carefully monitoring levels of radioactive materials released from the Fukushima Power Plant."
- "The DOD has always monitored and continues to monitor the air and water quality in and around US military installations. Environmental radioactivity levels in your area have been, and continue to be very low."
- "Internal monitoring is a safe and harmless way to determine if radioactivity was taken into the body."

- "To date, we have performed internal monitoring on over 5,000 (the number used at the time) Department of Defense personnel who were considered to have a higher potential for being exposed to radiation."
- "Approximately 98 percent of these individuals showed no detectable level of radiation above background levels. Among the 2 percent of those with detectable levels of radiation, none exceeded 0.030 rem. This amount can be compared to the dose resulting from taking two round-trip flights from Japan to the United States."
- "Because of the internal monitoring results to date, we neither recommend nor require this screening. We are offering this screening in good faith in order to address your personal concerns."

1.7 Overview of Internal Monitoring

Internal monitoring is a technique to estimate radiation doses to organs and tissues by measuring the amount of radioactive material in the human body. The process involves detection of the x- and gamma-ray radiation from the radionuclides taken into the body, calculation of the activity of each radioactive nuclide in the body at the time of measurement, back-calculation of the activity of each radionuclide to the time of intake into the body, and conversion of the intake activity into a radiation dose. Radiation dose determination from internal radiation sources (as determined through internal monitoring) and external radiation sources (as determined by other means such as the wearing of a personal dosimeter) are the principal components in performing health assessments following a radiological release. Internal monitoring is also routinely used in occupational health surveillance programs in those industries where workers have the potential to take radioactive material into their body as part of their employment. Internal monitoring measurements of activity in the body and calculation methods for performing assessments of dose to organs and tissues are well-established and standardized throughout the world.

Internal activity was measured for the whole body and for the thyroid using commercial fixed scanners and portable instruments. The portable instruments were used onboard ships and in the field at many locations. Both portable and fixed instruments were used at three locations (see Table 2). Intake Retention Fractions (IRFs) taken from the scientific literature or calculated in this program were used to convert the measured activity to an estimated intake activity. The exact day of intake was not always known, in which case an assumed intake date was estimated as discussed in the next section. Values of DCs were taken from the literature to convert estimated intake activity to a committed effective dose and a committed equivalent dose to the thyroid for each individual monitored. Specific and appropriate literature citations for IRFs and DCs are given in this report. Details of the dose calculations can be found in Section 5 of this report.

1.7.1. Assumed Intake Date

For use in the IM calculations, the earliest possible date for inhalation and ingestion was assumed to ensure the most conservative (highest) estimates of committed effective and equivalent doses. The assumed intake date for calculations was more accurately determined by interviews at the time each person was internally monitored. The people being internally monitored were asked to describe where they had been and what work they had performed prior to internal monitoring to ascertain when the first date of intake could have occurred. For

example, if a person left their duty station in Washington DC and entered into Japan 15 days after the March 11, 2011 earthquake the first possible intake date would be March 26, 2011. Choosing the earliest possible date of intake maximized the number of days between intake and monitoring so that the calculated dose would be conservative. The range of intake dates ranged from March 11, 2011, (the date of the initial 9.0 magnitude earthquake and subsequent tsunami) through May 11, 2011. The range of intake dates was determined by subtracting the reported "Number of days between first potential exposure" from the IM date listed. For example, a person with an estimated intake date of May 11, 2011, and monitored on May 18, 2011, had listed 7 days between first potential intake and the IM date. For each person, intakes were assumed to occur on a single day. Intakes could have occurred during all days that a person was in a potential exposure area but assuming that the entire intake occurred on the first day of potential internal exposure was conservative, and resulted in the highest calculated doses. The computer spreadsheet that automated the OT RIMIS dose calculation required the date of internal monitoring and the number of days after intake to be entered, prompting the staff to conduct interviews and determine the best date for the first potential exposure.

The first individuals with measureable intakes were monitored on March 16, 2011, Pacific Standard Time. These individuals were three shipyard employees working at Yokosuka NB who were monitored for internally-deposited radioactive material with a Canberra full-body and thyroid scanner upon their return to the United States. Their measured thyroid activities were 74–148 Bq (2–4 nCi), with calculated committed equivalent doses to the thyroid ranging from 0.11–0.22 mSv (0.011–0.022 rem). There were no measureable cesium intakes for these individuals.

1.7.2. Sources of Radioactive Material for Potential Intake

Loss of cooling and other damage at the FDNPS following the earthquake and tsunami produced various types of damage to reactor structures and resulted in the ultimate release of radioactive materials to the environment. At FDNPS, the major source of radioactive materials that were dispersed beyond the site boundary resulted from irradiated reactor fuel with failed cladding or that melted and released fission products and other radionuclides for transport in air or water media.

In its first report to the International Atomic Energy Agency (IAEA), the Government of Japan (GOJ) estimated releases of radioactive isotopes of iodine (I-131) and cesium (Cs-137) of 1.5×10^{17} Bq (4.0×10^{6} Ci) and 1.2×10^{16} Bq (3.2×10^{5} Ci), respectively, during the period March 11 to April 5, 2011 (GOJ, 2011a). The fuel of concern was limited to fuel in the cores of FDNPS Units 1, 2 and 3. Units 5 and 6 were able to maintain sufficient backup power to core cooling systems to avoid core damage and achieved stable cold shutdown by March 20, 2011; the Unit 4 core was empty (GOJ, 2011a). The second GOJ report to the IAEA with updated information about the FDNPS disaster provided a solid basis for ruling out any release of radioactive material from spent fuel pools in Units 1, 2, 5, and 6, as well as the site common spent fuel pool and the dry cask fuel storage facility (GOJ, 2011b).

Planned release of contaminated water containing approximately 1.5×10^{11} Bq (4.0 Ci) from the FDNPS site, as well as leakage of highly contaminated water originating from Units 2 and 3 containing approximately 4.7×10^{15} Bq (1.3×10^{5} Ci) and 2.0×10^{13} Bq (540 Ci), respectively, also resulted in transfer of radioactive materials offsite. These releases to the sea were dominated by radioactive isotopes of cesium and iodine (GOJ, 2011a).

The measured radiation dose rates taken at the main gate of FDNPS by Tokyo Electric and Power Company (TEPCO) over the period of interest as shown in Figure 1 and Figure 2 illustrate the sequence of airborne releases associated with the reactor. The data in Figure 2 are a subset of the data shown in Figure 1 for the purpose of expanding the time axis to better see the detail of the peaks during the period of March 10–19, 2011. For the time periods lacking reported values at the TEPCO main gate, measured values were obtained from nearby locations (e.g., west gate) and adjusted to be consistent with measurements at the main gate. Measurements of radioactive isotopes in air and soil indicated radionuclides at extended distances from the FDNPS over time. Those detections included the following:

- The noble gas Xe-133 was detected at the International Monitoring Station (IMS), Takasaki (Gunma Prefecture, about 210 km (130 miles) WSW of FDNPS) during the period March 15–29, 2011, and saturated the detector on March 15 while showing concentrations exceeding 1 kBq m^{-3} (27 nCi m^{-3}). Xe-133 concentrations decreased into the measureable range late on March 16 and tapered off, with intermediate activity concentration spikes on March 20 and March 21. (CTBTO, 2011)
- Radioactive isotopes of iodine (I-131 and I-132), cesium (Cs-134, Cs-136, and Cs-137), and tellurium (Te-132) were detected on March 12 indicating release of volatile radioactive materials from FDNPS Unit 1. Thereafter, detection of these isotopes and Te-129 and Te-129m coincided with the timing of peaks indicated in Figure 2 and further shown in GOJ (2011b).
- Ba-140 was detected in soil samples in Fukushima Prefecture, and Sr-89 and Sr-90 were measured on site at the FDNPS and in Fukushima Prefecture (GOJ, 2011a; GOJ, 2011b).
- Mo-99, Tc-99m, La-140, and Nb-95 were detected in aerosols and / or soil in several prefectures (GOJ, 2011a). The actinides Pu-238, Pu-239, Pu-240, Am-241, Cm-242, and Cm-244 were detected within short distances of the site boundaries of the FDNPS (GOJ, 2011a; GOJ 2011b).

These releases to the air, water, and soil combined with the external radiation dose rates contribute to the radiation doses received by exposed populations. External exposures contribute directly to doses received, while the concentrations of radioactive materials in air, water, and soil are associated with radiation dose when taken into the body by breathing air, drinking water, and ingesting soil. Fortunately, DOD-affiliated individuals were at considerable distances from the FDNPS ranging from 80–1,125 km (50–700 mi), except for a small number of individuals who visited J-Village, located about 20 km (12.5 mi) from FDNPS. However, these individuals had very short stay times at this location, typically on the order of a few hours.

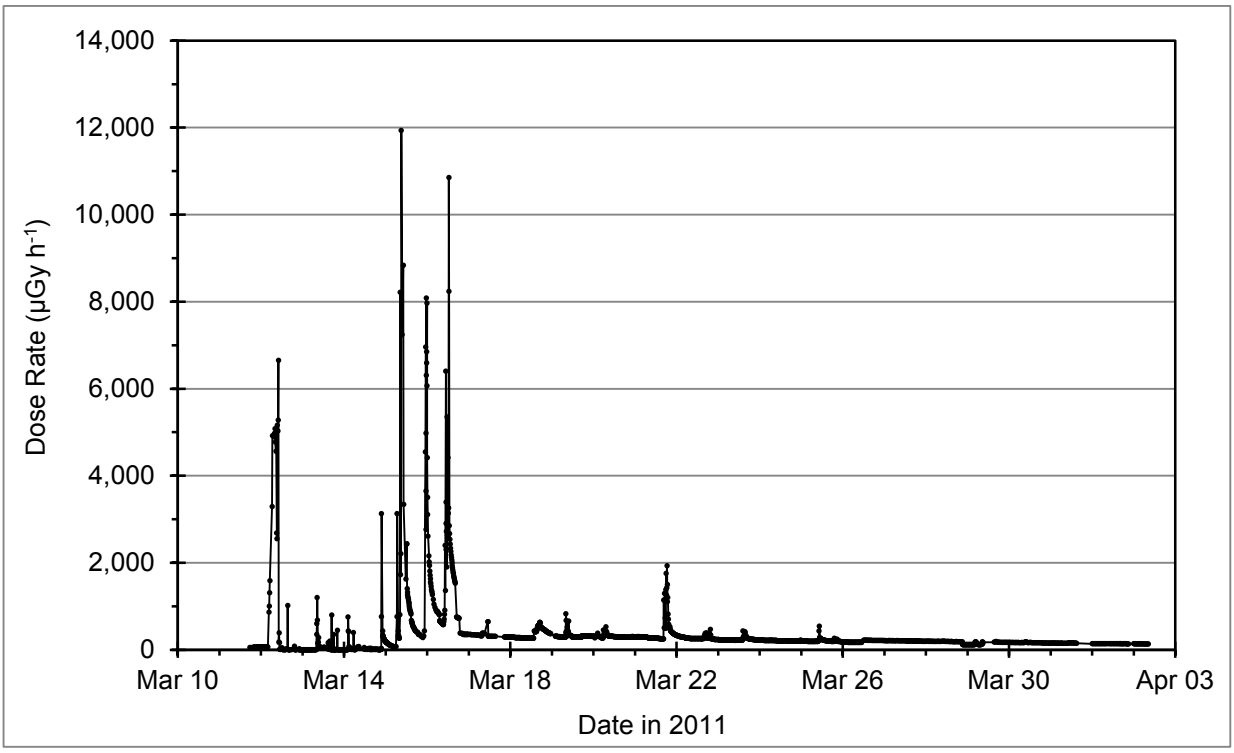

Figure 1. TEPCO dose rate measurements at the FDNPS main gate

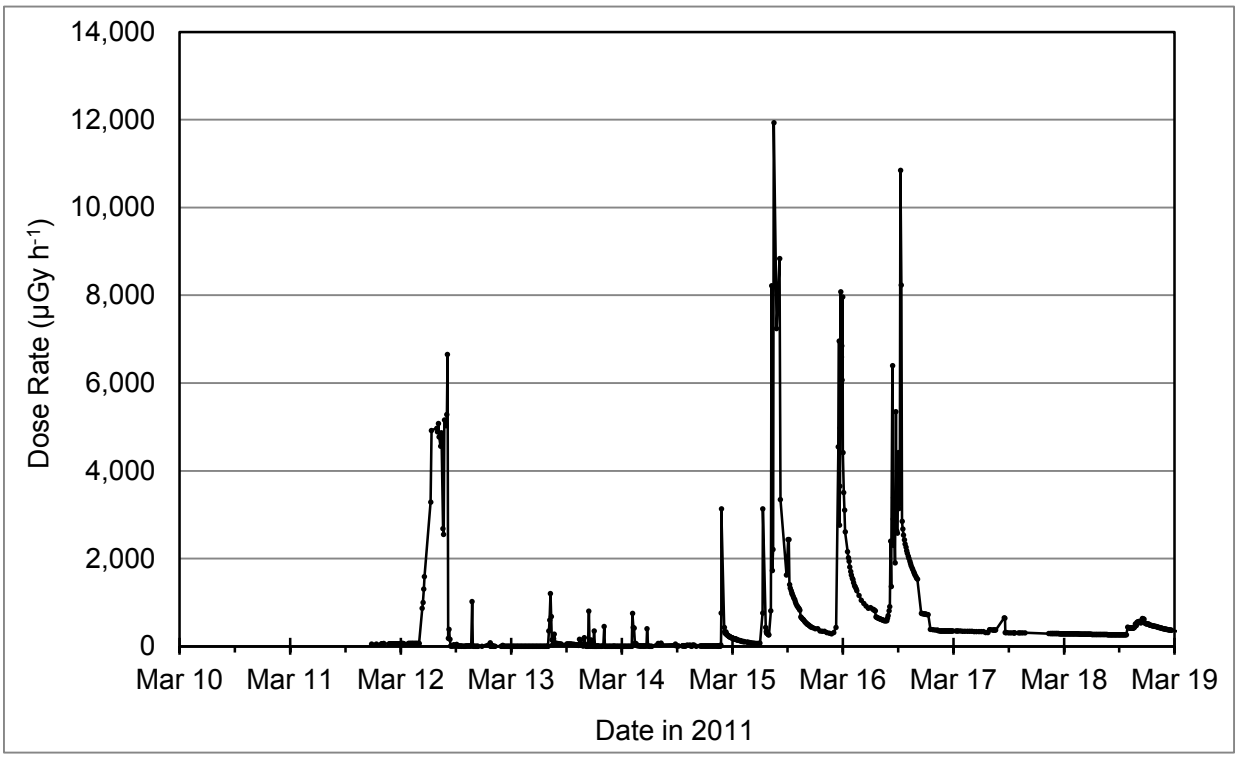

Figure 2. TEPCO dose rate measurements at the FDNPS main gate during the first week following the accident

1.7.3. Nuclides Included in Internal Monitoring Calculations

The nuclides of greatest concern for potential exposures to FDNPS releases are the radioactive isotopes of iodine, cesium, and tellurium. This is because they comprise the largest fractions of the radioactive material released from FDNPS and produce the greatest doses for the inhalation and ingestion pathways (Cassata et al., 2012).

As discussed previously, radioactive materials released from the reactor core into the environment can expose people to radiation either as external sources within the passing plume or after being deposited on the ground or as internal sources when taken into the body through inhalation or ingestion of various media that have become contaminated; i.e., the air they breathed, or the water or dirt they ingested.

The radioactive materials released during a nuclear reactor accident vary across a full spectrum of elements and their compounds, as well as in the variety of radionuclides with their respective radioactive half-lives, and physical properties. In order to deliver a dose to an organ or tissue, radiation from radioactive materials inside the body must reach an organ and/or tissue so that the organ/tissue will receive its dose. In general, for radioactive materials retained in specific organs or tissues, the organ or tissue containing the radioactive material receives the most significant dose. Some radioactive materials distribute almost uniformly throughout the body while others are retained and accumulate in specific organs. Those radionuclides that distribute uniformly include radioisotopes of cesium (e.g. Cs-134 and Cs-137). Those that tend to accumulate in specific organs include those from iodine (I-131, I-132, etc.) that accumulate in the thyroid gland, strontium (e.g., Sr-89 and Sr-90) that accumulate in the bones, and others.

The decision of which radioisotopes to be included in the OT RIMIS program was initially determined from a 1-m^3 air sample taken with a Portable Air Sampler (sample number W1100450) drawn on Barge YR-95, located on the waterfront in the Yokosuka NB on March 15, 2011, at 1838. The results of this sample analysis are listed in Table 4.

Table 4. Measured air activity concentrations at Yokosuka NB on March 15, 2011

Radio-nuclide	Air Activity (pCi m^{-3})*	Activity Ratio Relative to I-131	Activity Ratio Relative to Cs-137	Percent of Total Activity	Percent of Total Activity
I-131	3900	1.0	7.1	35.3	59.4
I-132	2100	0.5	3.8	19.0	
I-133	560	0.1	1.0	5.1	
Te-132	3500	0.9	6.3	31.7	31.7
Cs-134	430	0.1	0.8	3.9	9.0
Cs-137	560	0.1	1.0	5.1	

*Air activity was measured in units of pCi m^{-3}; multiply by 0.037 to convert to units of Bq m^{-3}.

The radionuclides measured as part of the OT RIMIS program were I-131, Cs-134, and Cs-137. The activity ratios shown in Table 4 were used to determine committed effective and committed equivalent dose ratios (scaling factors greater than unity used as multipliers on the measured dose) for the calculation of doses from all nuclides, i.e., those detected and not detected but assumed to be present. This allowed for a calculation of dose from all six nuclides

listed as long as any one nuclide could be detected by IM, i.e., a measurement greater than the critical level for detection (see Section 2.2.5). When more than one nuclide (I-131, Cs-134, and Cs-137) was detected during IM, the dose ratios were calculated for each radionuclide detected, and then the detected nuclide that resulted in the greatest total committed effective and equivalent doses was used. This was a conservative assumption used to account for the greatest potential committed effective and equivalent doses reported to an individual. Details of this calculation can be found in Section 5.

To support the choices of radionuclides and the activity concentration proportions shown in Table 4, two-month average measured activities and dose information for Yokota Air Base (AB) from Cassata et al. (2012) are included in Table 5 for comparison. Similar contributions to air concentrations were observed at the other major locations occupied by DOD-affiliated individuals during OT (Cassata et al., 2012). Comparisons of the percentage contributions of the air activity concentrations for the two data sets from Table 4 and Table 5 are shown in Table 6.

Table 5. Relative contributions to radionuclide concentrations and doses at Yokota AB

	Air Inhalation			Water Ingestion			Soil Ingestion		
Radionuclide	**[A]***	**E(τ)†**	**$H_{T,\tau}$‡**	**[A]***	**E(τ)†**	**$H_{T,\tau}$‡**	**[A]***	**E(τ)†**	**$H_{T,\tau}$‡**
All Iodine	65.7%	84.7%	92.7%	86.3%	89.7%	99.4%	50.6%	70.1%	95.0%
All Tellurium	29.1%	9.5%	7.0%	-	-	-	24.6%	5.9%	3.3%
All Cesium	4.3%	5.8%	0.3%	13.7%	10.3%	0.6%	24.8%	24.0%	1.6%
All Others	0.9%	0.1%	0.0%	-	-	-	0.1%	0.0%	0.0%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%
Dose (rem)	N/A§	0.018	0.33	N/A	0.010	0.172	N/A	0.0000	0.0015

* [A] is percent of total activity concentration in the stated medium for each radionuclide group and Total.
† E(τ) is percent of total committed effective dose from the route of entry for this radionuclide group except for Dose, which is in units of rem.
‡ $H_{T,\tau}$ is percent of total committed equivalent dose to thyroid from the route of entry for this radionuclide group except for Dose, which is in units of rem.
§ "N/A" means "not applicable," signifying that an activity value is not appropriate for a dose entry.

Table 6. Comparison of radionuclide percent contributions to air activity contentrations from Tables 4 and 5

Radionuclide	Percent of Total Activity from Table 4	[A]* from Table 5	Difference†
All Iodine	59.4%	65.7%	-6.3%
All Tellurium	31.7%	29.1%	2.6%
All Cesium	9.0%	4.3%	4.7%
All Others	0.0%	0.9%	-0.9%

* [A] is percent of total activity concentration in the stated medium for each radionuclide group.
† Difference is {Percent of Total Activity from Table 4} −{[A] from Table 5}.

The differences in percent contributions range from -6.3 to +4.7 percent, which are relatively small differences, thus validating the use of the radionuclide air concentration ratios from the Barge YR-95 data provided in Table 4 for all of the OT RIMIS scaling calculations, i.e.,

multiplying the greatest measured dose from I-131, Cs-134, or Cs-137 by a multiplying factor greater than unity (1.0) to account for all nuclides listed in Table 4.

For completeness Table 7, Figure 3, and Figure 4 are shown below from Cassata et al. (2012). Table 7 lists the two-month doses for Yokota AB. The external doses shown are the results of calculations using ambient radiation exposure measurements from the environment and internal doses are the result of calculations using the activity concentrations provided in Table 5. Figure 3 and Figure 4 illustrate the same information provided in Table 7 but in pie chart form.

Table 7. Contributions to doses from external and internal radiation at Yokota AB

Source	Dose (rem)		Percent Contribution	
	$E(\tau)^*$	$H_{T,\tau}^\dagger$	$E(\tau)^*$	$H_{T,\tau}^\dagger$
External Radiation	0.027	0.027	49.7	5.2
Internal Radiation				
Inhalation	0.018	0.328	32.4	62.0
Water Ingestion	0.010	0.172	17.7	32.5
Soil Ingestion	<0.001	<0.001	0.2	0.3
Total Internal	0.028	0.502	50.3	94.8
Total	**0.055**	**0.530**	**100**	**100**

* $E(\tau)$ is effective dose from external radiation or committed effective dose from internal exposure

† $H_{T,\tau}$ is equivalent dose from external radiation or committed equivalent dose from internal exposure to the thyroid

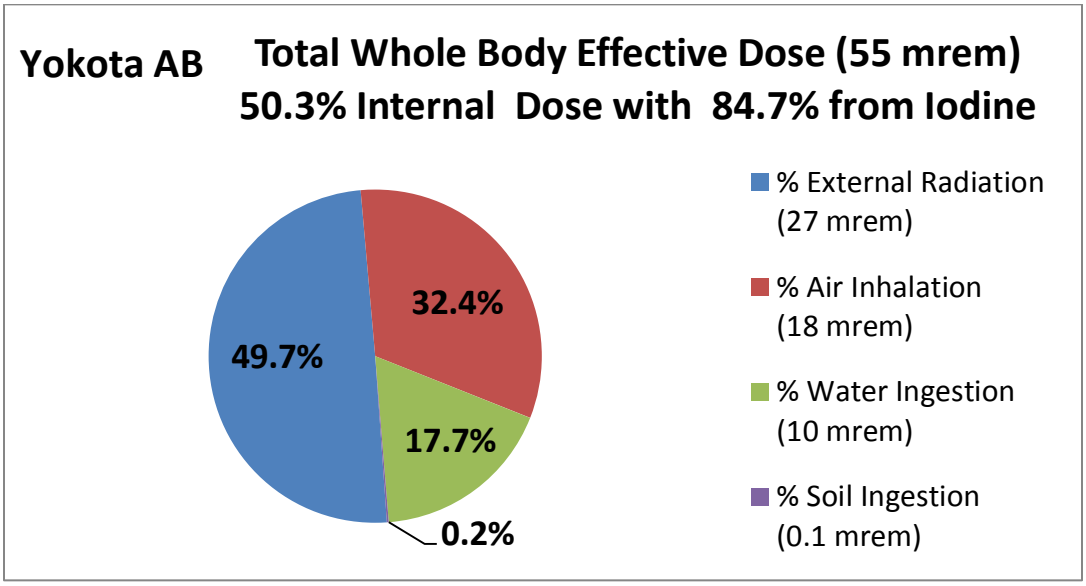

Figure 3. Percent contributions from external, air, water, and soil pathways to effective dose

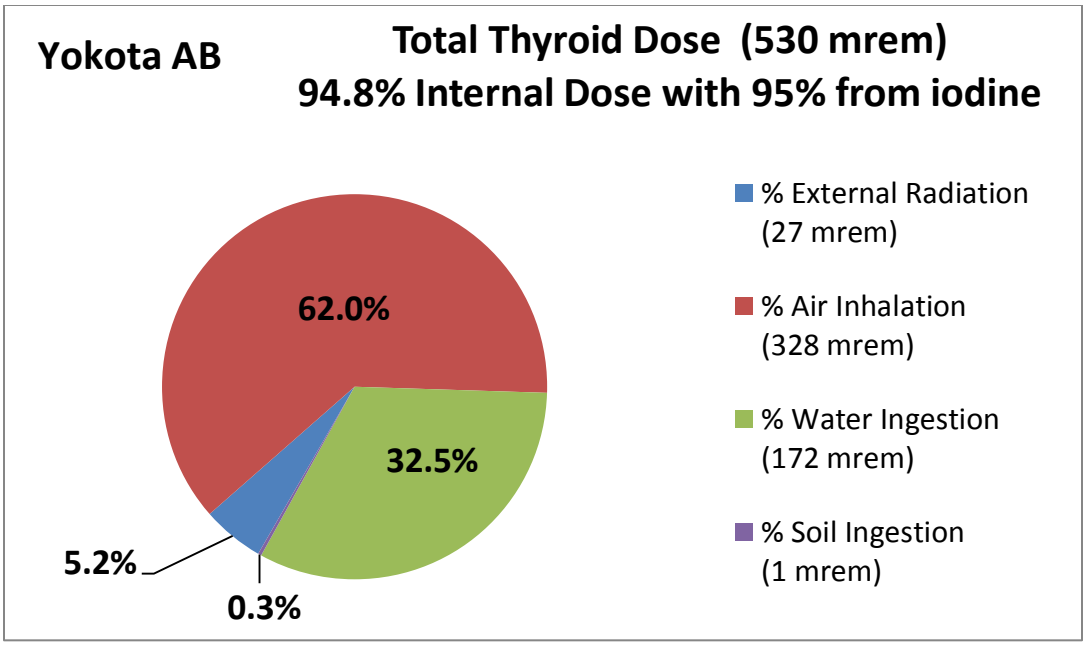

Figure 4. Percent contributions from external, air, water, and soil pathways to thyroid dose

1.7.4. Mode of Intake and Form of Radionuclides

In order to rapidly develop and implement the OT RIMIS program consistent with the program objectives, it was necessary to make assumptions about the mode of intake of radioactive material, and the physical and chemical forms of environmental radionuclides. It was necessary to know or assume these parameters because they determined which DCs and IRFs to use from the literature. For the OT RIMIS program, the following three assumptions were made: (1) all intakes were acute, (2) all intakes were via inhalation, and (3) all iodines were in aerosol form.

1.7.4.1 Acute Intakes

Assuming an acute intake at the earliest possible date of intake rather than a chronic intake during several days or longer was a simplifying assumption that resulted in higher calculated doses.

1.7.4.2 Intake via Inhalation

It was assumed that inhalation was the most likely mode of intake radionuclides for the majority of DOD-affiliated individuals in the program because most of these individuals were assumed to have consumed bottled water or tap water from underground sources (e.g., wells) that would not have become contaminated. Therefore, the contribution of water to dose would have been negligible. In contrast, Cassata et. al., (2012) assumed that everyone drank from contaminated surface water supplies, which resulted in a high-sided value of 32 percent contribution to thyroid dose from water ingestion. Chehata et al. (2013) showed that the doses in Cassata et. al. (2012) were greater than the 95.8th percentile of the distribution of estimated doses from probabilistic calculations.

Another point to remember is that in-vivo monitoring methods measure the activity of radioactive materials in the body regardless of the mode of intake to the body. For example, when measuring the activity of radioactive iodine in the thyroid the detectors respond to the radiations from all the radioactive iodine in the thyroid whether it came from inhalation or ingestion. Assuming intake was via inhalation only affected the values of IRFs and DCs chosen and not the actual amount of radioactive iodine measured in the thyroid. The calculation of thyroid dose resulting from inhalation and ingestion would require dividing the measured total thyroid activity into two components—one from inhalation and the other from ingestion. Then, the IRFs and DCs for inhalation and ingestion would be applied to each activity fraction to determine a dose from both inhalation and ingestion.

Based on additional information on food and water sources for DOD-affiliated individuals it was assumed that the dose from the ingestion pathway was negligible making the calculation of dose from inhalation and from ingestion unnecessary. Finally, since all activity in the body was measured by the IM systems, the effect of assuming a particular pathway is reduced. The differences in the calculated dose from one pathway compared to another comes down to the differences in the IRFs and DCs for the individual pathways; i.e., if one assumes that the pathway is inhalation, then inhalation IRFs and DCs would be used, whereas if one assumes that ingestion is the pathway, then ingestion IRFs and DCs would be used. Dose calculations for contributions from inhalation and ingestion require assumptions about the fractions of activity from each pathway and result in a weighted average dose from the activities for each pathway using the specific IRFs and DCs.

1.7.4.3 All Iodines were in Aerosol Form

It was also assumed that all radionuclides (including radioiodines) were inhaled as aerosols with a particle size distribution having an activity median aerodynamic diameter (AMAD) of 1 μm, and that they were in a chemical form corresponding to ICRP absorption Type F (Fast). This did not present any issues for cesium measurements because there are no common environmental gaseous forms of cesium. However, for iodine, which does occur commonly in both aerosol and gaseous forms, additional consideration was necessary. For OT RIMIS calculations, gaseous (to include elemental and organic) forms of radioiodines were not included because information about the actual forms of radioiodines inhaled was not available at the time the calculation methods were being developed and employed. Furthermore, all radioiodine inhaled by individuals was assumed to be I-131, since it is the longest lived iodine isotope considered in OT RIMIS calculations (half lives for I-131, I-132, and I-133 are 8.04 d, 2.3 h, and 20 h, respectively). The following discussion demonstrates that using these assumptions does not result in a smaller dose.

An analysis of relative contributions to dose from radioiodines was performed to evaluate whether the assumption that inhalation of I-131 aerosols results in a conservative estimate of dose to the thyroid compared to the doses resulting from other assumptions about the radioisotopic mix of radioiodines and various physical forms. The analysis discussed here compares the relative doses (committed effective and committed equivalent) to the thyroid for two options—Option 1, a "true iodine condition" and Option 2, an "all aerosol I-131" condition, as described in the following:

- Option 1 calculations assume that the radioiodines are characterized by the two-month average air concentrations measured at Yokota AB for the three isotopes of iodine (I-131,

I-132, I-133) in air comprised 71.5 percent gaseous form and 28.5 percent aerosol form. The with the gaseous fraction was composed of 2/3 methyl iodide and 1/3 elemental iodine (Cassata et al., 2012).

- Option 2 calculations assume the radioiodines are characterized entirely by I-131 in aerosol form.

This evaluation compares the relative doses for both options. The relative dose is the iodine activity fraction weighted average of the DCs. The percentage contribution to air activity of each radioiodine, the DCs, and the results of the calculations are shown in Table 8. The ratios of the relative dose contributions from Option 2 to those from Option 1 are shown for the committed effective and committed equivalent dose at the bottom of the table. In each case, the ratio value of 1.5 supports a conclusion that the doses calculated with the assumption that all radioiodines are represented by I-131 in aerosol form are conservative. This conclusion is reasonable because the DCs for all forms of I-132 and I-133 are smaller than the DC for I-131 aerosol.

Further analysis of inhaled gaseous methyl iodide and aerosol iodine show that they have about the same biokinetics and thus about the same IRF function with time. Detailed studies of the deposition and subsequent biokinetics of inhaled methyl iodide have been conducted in human volunteers. The amount retained varied from 50 to 90 percent (average 70 percent), increasing with decreasing number of breaths per minute (ICRP, 1995). Absorption to blood of the deposited activity was very rapid (estimated half-time about 5 s) and subsequent biokinetics were very similar to those of injected iodide (ICRP, 1995). ICRP Publication 71 (ICRP, 1995) lists methyl iodide as a class SR-1 (70% deposition), with Type V clearance. The extrapolation of aerosol IRFs back to the time of intake results in an inhalation retention of about 80 percent. Aerosol iodine also is absorbed rapidly into the blood (ICRP, 1995) with a half-time of about 10 minutes so that the intake of gaseous (methyl iodide) or aerosol iodine would behave similarly in the body and the IRF function with time for these two forms would be about the same. Therefore, assuming all aerosol iodine is a valid assumption as far as initial retention and the kinetics of the elimination of iodine from the body over time (i.e., the IRF function).

Table 8. Comparison of doses for inhalation of radioiodines in mixed aerosol and gaseous form with I-131 aerosols only

Option 1 ("True Iodine Condition")*										
Form	**Aerosol**	**Methyl Iodide**	**Elemental Iodine**	**Aerosol**	**Methyl Iodide**	**Elemental Iodine**	**Aerosol**	**Methyl Iodide**	**Elemental Iodine**	**Result**
Isotope	I-131	I-131	I-131	I-132	I-132	I-132	I-133	I-133	I-133	Sum
% of Total Activity	6.31%	10.55%	5.28%	11.97%	20.01%	10.00%	0.44%	0.74%	0.37%	65.68%
% of Iodine Activity	**9.6%**	**16.1%**	**8.0%**	**18.2%**	**30.5%**	**15.2%**	**0.7%**	**1.1%**	**0.6%**	**100.0%**
$E(\tau)$ DC†	7.4E-09	1.5E-08	2.0E-08	9.4E-11	1.9E-10	3.1E-10	1.5E-09	3.1E-09	4.0E-09	
$H_{T,\tau}$ DC†	1.5E-07	3.1E-07	3.9E-07	1.4E-09	3.2E-09	3.6E-09	2.8E-08	6.0E-08	7.6E-08	**Relative Dose**
% × $E(\tau)$ DC	7.1E-10	2.4E-09	1.6E-09	1.7E-11	5.8E-11	4.7E-11	1.0E-11	3.5E-11	2.3E-11	4.9E-09
% × $H_{T,\tau}$ DC	1.4E-08	5.0E-08	3.1E-08	2.6E-10	9.7E-10	5.5E-10	1.9E-10	6.8E-10	4.3E-10	9.9E-08
Option 2 ("All Aerosol I-131")‡										
Form	**Aerosol**									**Result**
Isotope	I-131									Sum
% of Total	6.31%									6.31%
% of Iodine	**100.0%**									**100.0%**
$E(\tau)$ DC	7.4E-09									
$H_{T,\tau}$ DC	1.5E-07									**Relative Dose**
% × $E(\tau)$ DC	7.4E-09									7.4E-09
% × $H_{T,\tau}$ DC	1.5E-07									1.5E-07
Ratio of Relative Dose for Option 2 to Relative Dose for Option 1										**Ratio**
$E(50)$ Option 2 / $E(50)$ Option 1										1.5
$H_{T,50}$ Option 2 / $H_{T,50}$ Option 1										1.5

* Option 1 assumes (I-131, I-132, and I-133), 71.5% gas (2/3 methyl iodide, 1/3 elemental iodine; Type V, Class SR-1), 28.5% aerosol (1 μm AMAD, Type F)

† DC data from ICRP Publication 71 for adults in units of Sv Bq^{-1}

‡ Option 2 assumes 100% of radioiodines as I-131 in aerosol form (1 μm AMAD, Type F)

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Section 2.

Equipment Description, Operation, and Calibration

This section provides a description of the IM equipment used in the OT RIMIS program. Basic physical descriptions of the equipment and technical specifications are provided for both the fixed full-body scanners and portable instruments (E-600/SPA-3). In addition, laboratory and field calibration procedures, variability, and MDA for the portable instruments are discussed.

2.1 Fixed Systems

Two models of Canberra full-body scanning systems were used as the fixed monitors in the OT RIMIS program: an ACCUSCAN-II scanning whole body counter using high-purity germanium detectors, and a FASTSCAN high-throughput, whole body counter using two thallium activated, sodium iodide [NaI (Tl)] detectors.

Implementation of the OT RIMIS program involved detailed planning and inter-service cooperation. One ACCUSCAN-II system, weighing 4,000 kg (8,700 lb) and two FASTSCAN systems, weighing 4,800 kg (10,600 lb) each were located, shipped to Japan, and prepared for operation. Much of the coordination and setup effort was performed by personnel of the Puget Sound Naval Shipyard and Intermediate Maintenance Facility (PSNS & IMF). The process for locating available units, obtaining approval for their use, and deployment to Japan required coordination of the details for each as discussed in the following (PSNS, 2013):

- ACCUSCAN II at Atsugi NAF. This was a new unit purchased through Knolls Atomic Power Laboratory immediately following the March 11, 2011, event in Japan. The unit was at the vendor ready for another customer in Europe. The vendor recognized the need in Japan, arranged to sell the unit to the Navy, and shipped the unit to Guam. From there the unit was air-lifted by the U.S. Air Force to Yokota AB and then trucked to Atsugi NAF.
- FASTSCAN at U.S. Naval Activities, Yokosuka NB. This was a new unit located at Portsmouth Naval Shipyard that was neither assembled nor in use there. The U.S. Air Force air-lifted this unit to Yokosuka NB via Yokota AB.
- FASTSCAN at U.S. Naval Hospital, Okinawa. This unit was originally located at Point Loma NB, San Diego, CA. It was operational and in use by PSNS & IMF Detachment San Diego. The unit was trucked from San Diego to Travis Air Force Base, CA, and then air-lifted by the U.S. Air Force to Okinawa.
- All three units were assembled and tested at the Japan locations by two PSNS & IMF personnel (a senior Health Physicist and a senior Radiac Calibration Laboratory electrical mechanic).

2.1.1. Canberra ACCUSCAN II Description and Operation

The ACCUSCAN II system was equipped with two 25 percent coaxial moveable germanium detectors and a shadow shield formed from two components—a personnel shield of

10 cm (4 in) of low background steel and a detector shield of 5 cm (2 in) of lead around the detector. The ACCUSCAN II was configured to detect gamma-ray photons with energies between 100 keV and 1,336 keV. The system was supplied with ABACOS ™ software, which was used to process the scanning data. A picture and diagram of the ACCUSCAN II counter are shown in Figure 5 (Canberra, 2002a). The germanium detectors were attached to liquid nitrogen tanks for cooling to reduce electronic noise or interference. In normal operation the tanks and detector moved vertically as a single unit performing a 10-minute scan of the person standing inside the enclosure.

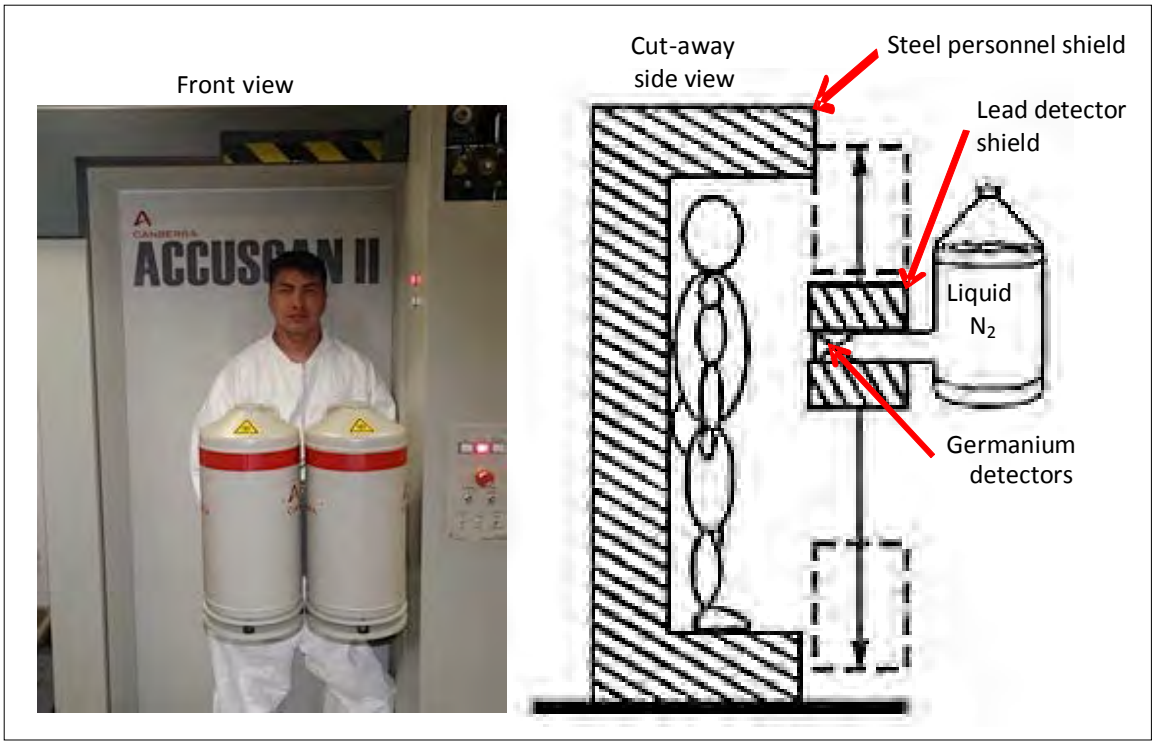


Figure 5. Canberra ACCUSCAN II

The ACCUSCAN II system was set up, calibrated, and operated according to PSNS & IMF guidelines for internal monitoring (PSNS, 2012a) as supplemented with specific procedures for use during OT in Japan (PSNS, 2012b). A full gamma spectrum (Figure 6) was obtained for both a whole body and thyroid measurement with a single scan. The lower portion of the figure displays the full energy range of detected photons. The upper portion of the figure displays the segment of the spectrum outlined by the box expanded to full horizontal scale, and with the 364.3 keV gamma ray of I-131 denoted by the cursor.

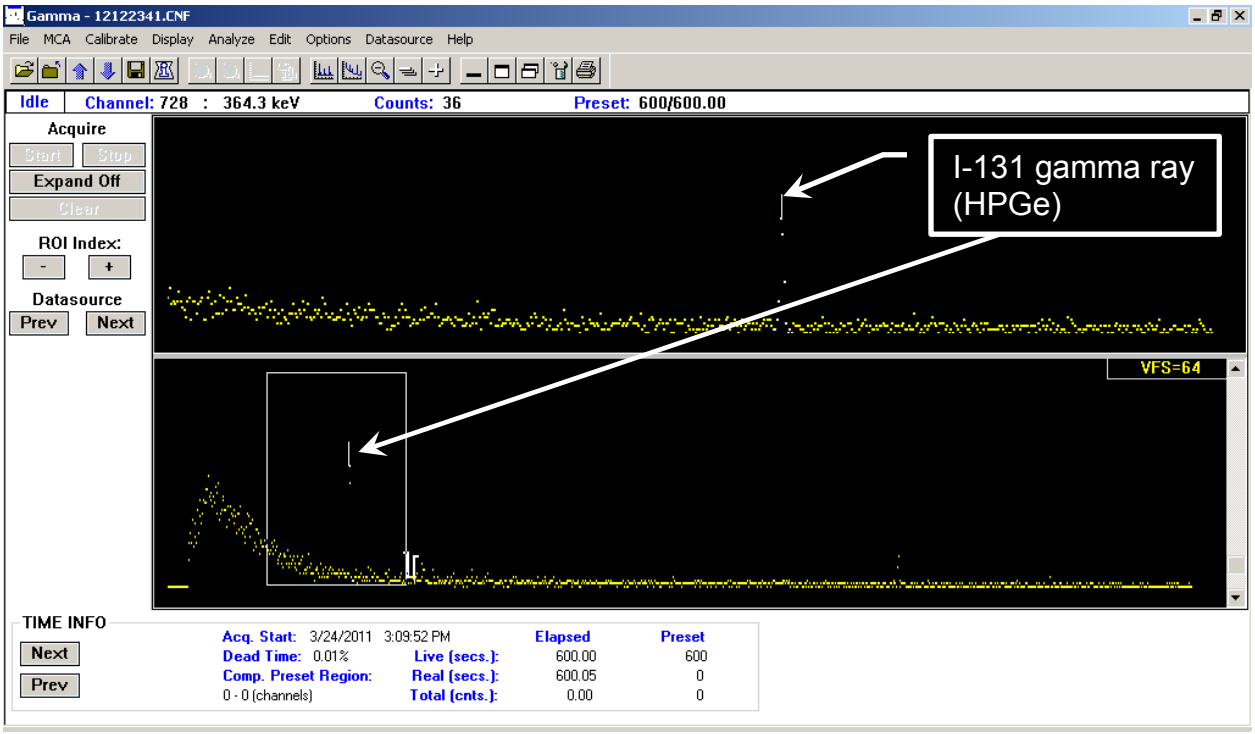


Figure 6. Screenshot of ACCUSCAN II gamma spectrum from an IM subject showing full energy range (lower segment) and energy range of selected box (upper segment)

Adults and children shorter than 122 cm (48 in) were scanned using the E-600/SPA-3 or the ACCUSCAN II because the detectors were capable of being placed in a stationary position at an optimal height for the thyroid and chest or back measurements. For these individuals, the ACCUSCAN II was used in the stationary mode with detectors centered 5 cm (2 in) above the bottom of the sternum, and the individual was given a small riser to stand on to create a clearance of at least 5 cm (2 in) but not more than 30 cm (12 in) above the floor. Infants were only scanned with an E-600/SPA-3 instrument. Age was not the determining factor for deciding who was a child or infant; any individuals who could be comfortably held on the chest of an adult were considered to be infants.

2.1.2. Canberra Model 2250 FASTSCAN Description and Operation

Fixed and thyroid IM were also performed using a Canberra Model 2250 FASTSCAN High-Throughput Whole Body Counter. The FASTSCAN system was equipped with two fixed large area 7.6 cm × 12.7 cm × 40.6 cm (3 in × 5 in × 16 in) NaI(Tl) detectors and two shadow shields of 10 cm (4 in) of steel. The instruments used were capable of detecting gamma-ray photons with energies between 300 keV and 1.8 MeV. The system was supplied with ABACOS software, which was used to process the data (Canberra, 2002b). A picture of a Canberra FASTSCAN counter is shown in Figure 7.

Figure 7. Canberra FASTSCAN

The FASTSCAN detection efficiency for x- and gamma-ray photons was a function of vertical position (Figure 8, [Bronson et al., n.d.]) because the FASTSCAN system used fixed detectors. Adults and children shorter than 122 cm (48 in) were scanned using the E-600/SPA-3 or the ACCUSCAN II. The optimal minimum height for FASTSCAN use was 145 cm (57 in). However, adults and children in the height range of 122–145 cm (48–57 in) were adequately scanned with an efficiency of 75 to 90 percent of the optimum value. Adults and children less than 122 cm (48 in) tall were scanned adequately using a short stepstool to bring their effective height to a minimum of 122 cm (48 in). Infants (i.e., any individual who could be comfortably held on the chest of an adult) were only scanned with an E-600/SPA-3 instrument.

During OT RIMIS, the FASTSCAN systems were set up, calibrated and operated according to PSNS & IMF guidelines for internal monitoring (PSNS, 2011) as supplemented with specific procedures for use during OT in Japan (PSNS, 2012c). In normal operation, a 6-minute scan of the person standing inside the enclosure was performed to obtain a full gamma spectrum (Figure 9).

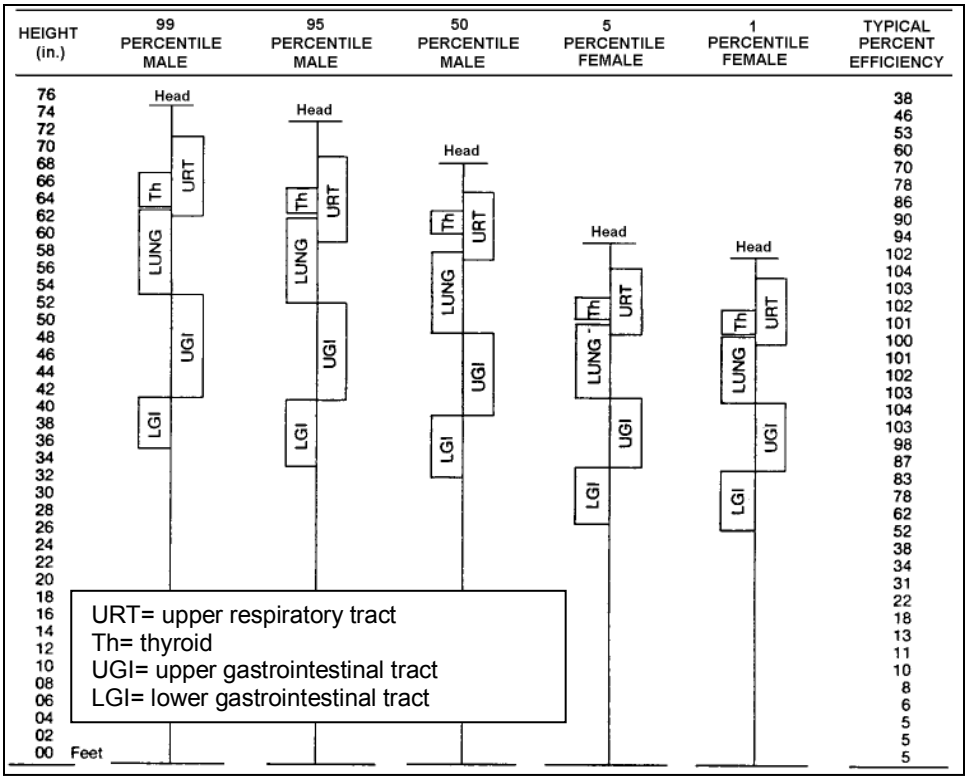


Figure 8. Canberra FASTSCAN detector efficiency as a function of height

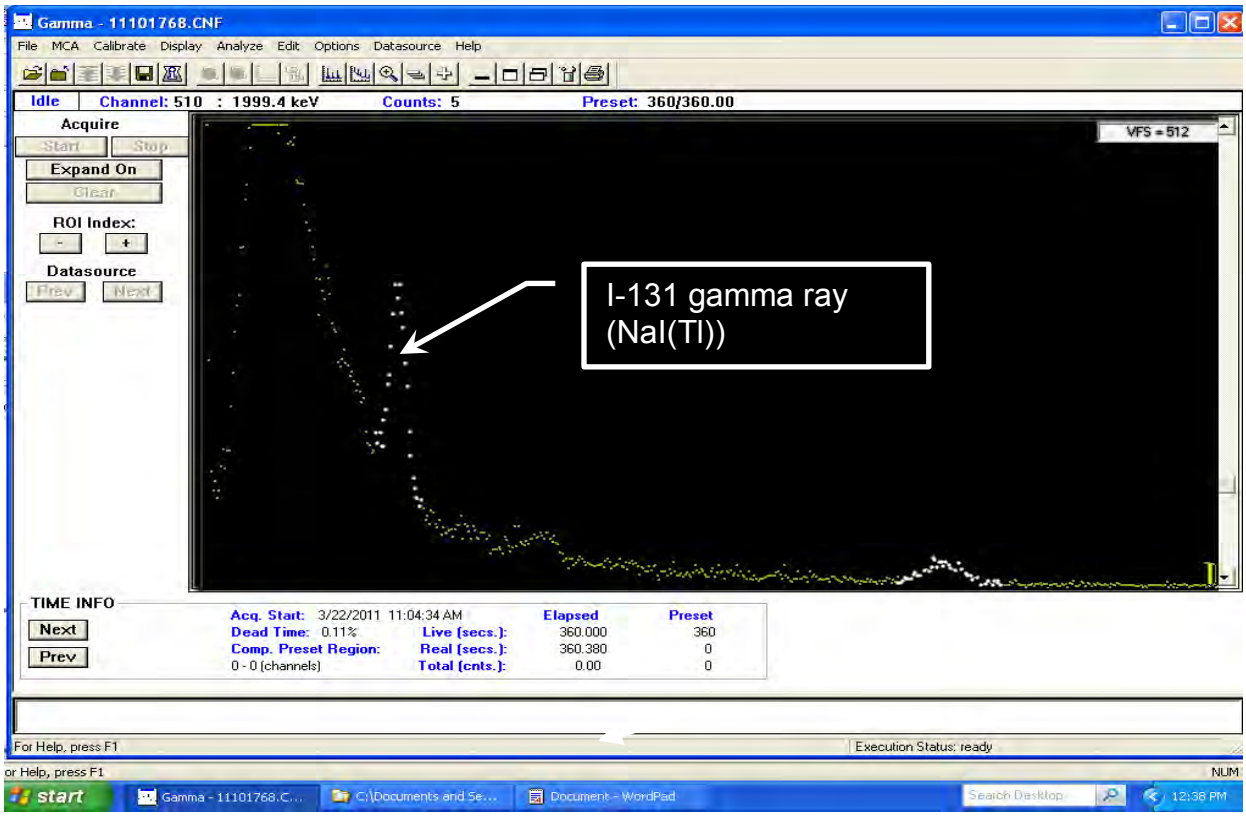


Figure 9. Screenshot of FASTSCAN gamma ray spectrum from an IM study

2.2 Portable Instrument System

The portable instrument system for IM comprised the Eberline E-600 multipurpose survey meter and the SPA-3 scintillation detector. The specifications, setup, and calibration of this system are discussed in the following subsections.

2.2.1. Eberline E-600/SPA-3 Instrument Description and Operation

Internal monitoring measurements of the thyroid gland and whole body chest were performed using an Eberline E-600 multipurpose survey meter equipped with a SPA-3 scintillation detector. The E-600 was capable of operating in rate-meter, scaler, integration, peak trap, and background mode (Thermo Electron, 2004). The SPA-3 probe is a scintillation detector with a 5 cm × 5 cm (2 inch × 2 inch) NaI(Tl) detector housed in an aluminum case. The SPA-3 probe was capable of detecting photons with an energy range of 60 keV to 2 MeV. The SPA-3 probe typically over-responded to photons at 100 keV by a factor of 10 and under-responded to photons at 1 MeV by a factor of 0.5 relative to its response to photons from Cs-137. (Johnson, 2009) Pictures of an E-600 survey meter and a SPA-3 probe are shown in Figure 10.

Figure 10. Eberline E-600 meter (at left) and SPA-3 detector (at right)

The E-600/SPA-3 pair was used in the open window mode to ensure it was responsive to all gamma- and x-ray radiation energies from approximately 60 keV to 2 MeV. There were a total of twenty-five pairs of E-600/SPA-3 instruments used for OT RIMIS operations.

Stands were built for the SPA-3 probes to keep them in a stationary position throughout the day. Once the first set of daily background counts was taken for an E-600/SPA-3 set, it was not moved, so that any positional variations in the background count were avoided. As shown in

Figure 11, some stands held two SPA-3 probes so that simultaneous 10-minute thyroid and chest measurements could be made. Thyroid measurements for I-131 were made by placing the SPA-3 probe against the throat, and a representative whole-body measurement of Cs-134 and Cs-137 was made by placing the SPA-3 probe against the chest. As shown in Figure 12, other stands held only a single SPA-3 probe. When single-probe stands were used, one 10-minute measurement was used for the thyroid and another 10-minute measurement was used for the chest or back. Each single-probe stand housed its own SPA-3 probe so that each probe remained in the same position for the entire day.

Figure 11. Stands holding two SPA-3 probes on USS Fitzgerald (DDG-62)

Figure 12. Stands holding one SPA-3 probe

Generally, for most E-600/SPA-3 IM measurements the SPA-3 probe was unshielded. Only when a child or infant was monitored were shielded probes used to lower the background count and MDA. Shielding was provided by wrapping the SPA-3 probe with two 15 cm × 30 cm × 1.3 cm (6 in × 12 in × 0.5 in) tungsten sheets as shown in Figure 12 and Figure 13. Infants were scanned only with an E-600/SPA-3 instrument. Age was not the determining factor for deciding who was a child or infant; any individuals who could be comfortably held on the chest of an adult were considered to be infants. Monitoring of a child with an E-600/SPA-3 system is depicted in Figure 14, which also shows the arrangement for obtaining a background count for a child or infant.

Figure 13. Tungsten sheets used to shield SPA-3 probe

Figure 14. Depiction of IM being done on a child (left photo) and child/infant background count being taken (right photo)

2.2.2. Laboratory Calibration

Calibration of the E-600/SPA-3 was required to convert net counts per minute (cpm) to I-131 activity retained in the thyroid or to total cesium activity (Cs-134 plus Cs-137) retained in

the whole body. Net cpm was obtained by subtracting the background count rate from the gross count rate.

The E-600/SPA-3 instruments were calibrated using discrete I-131 and Cs-137 sources traceable to the National Institutes of Standards and Technology that were placed in neck and lung phantoms. The calibrations provided by these nuclides are also valid for the other isotopes of iodine and cesium because of the similarities in their prominent photon energies, as shown in Table 9 for radioiodines and Table 10 for Cs-134 and Cs-137.

The iodine calibration factor was determined to be 0.0053 nCi cpm^{-1} (0.20 Bq cpm^{-1}) (Selwyn, 2011). Appendix E contains a copy of the memorandum documenting the iodine calibration factor determination.

Laboratory measurements showed that when a SPA-3 probe was placed at the neck (thyroid) or chest, it detected radiation from the entire body, not just from the location of interest. This radiation "cross talk" between measurement locations—essentially 100 percent for an unshielded probe—resulted in inaccurate and unreliable thyroid measurements. Therefore, the net count rate (gross minus background) from the chest (or back for females) was subtracted from the net thyroid count rate to ensure that the detector response related to radioactive material deposited in other parts of the body was not incorrectly attributed to radioactive material retained in the thyroid gland. The net chest (or back) count rate was used to determine whole body activity with no subtraction of the net thyroid count rate. Any cross talk from I-131 in the thyroid if present would add to the chest measurement and make the dose calculation more conservative.

The cesium calibration factor was determined to be 0.179 nCi cpm^{-1} (6.6 Bq cpm^{-1}) by the Knolls Atomic Power Laboratory (KAPL) in Schenectady N.Y. using a chest phantom with two discrete sources of Cs-137 (traceable to a national standard). However, as will be discussed later in this report, these laboratory calibration results did not correlate well with calibrations based on actual measurements of individuals who were measured with both the portable E-600/SPA-3 and fixed scanners. This was possibly due to the limited distribution of cesium in the chest phantom used in the laboratory as compared to the more uniform distribution of cesium in the human body. Therefore, field calibration procedures were developed and used for the cesium calibration, as described in the next section.

Table 9. Selected decay characteristics of I-131, I-132, and I-133

Gamma photons with yield ≥ 1%	I-131*		I-132*		I-133*	
	Gamma energy (keV)	Gammas per disintegration	Gamma energy (keV)	Gammas per disintegration	Gamma energy (keV)	Gammas per disintegration
Gamma 1	364.48	0.812	667.69	0.987	529.87	0.863
Gamma 2	636.97	0.073	772.60	0.762	875.33	0.045
Gamma 3	284.30	0.061	954.55	0.181	1298.22	0.023
Gamma 4	80.18	0.026	522.65	0.161	510.53	0.018
Gamma 5	722.89	0.018	630.22	0.137	706.58	0.015
Gamma 6			1398.57	0.071	1236.41	0.015
Gamma 7			812.20	0.056	856.28	0.012
Gamma 8			671.60	0.052		
Gamma 9			505.90	0.050		
Gamma 10			669.80	0.049		
Gamma 11			727.20	0.032		
Gamma 12			1136.03	0.030		
Gamma 13			809.80	0.029		
Gamma 14			650.60	0.027		
Gamma 15			1372.07	0.025		
Gamma 16			727.00	0.022		
Gamma 17			1295.30	0.020		
Gamma 18			621.20	0.016		
Gamma 19			262.70	0.014		
Gamma 20			1442.56	0.014		
Gamma 21			1143.40	0.014		
Gamma 22			547.10	0.013		
Gamma 23			780.20	0.012		
Gamma 24			1921.08	0.012		
Gamma 25			1290.70	0.011		
Gamma 26			729.50	0.011		
Gamma 27			1173.20	0.011		
Gamma 28			2002.30	0.011		
Gamma 29			876.80	0.011		
Individual Isotope Total		0.990		2.839		0.991

* Decay data are from Eckerman et al. (1993).

Table 10. Selected decay characteristics of Cs-134 and Cs-137

Gamma photons with yield ≥ 1%*	Cs-134		Cs-137	
	Gamma-ray energy (keV)	Gammas per disintegration	Gamma-ray energy (keV)	Gammas per disintegration
Gamma 1	604.70	0.976	661.64†	0.849
Gamma 2	795.84	0.854		
Gamma 3	569.32	0.154		
Gamma 4	801.93	0.087		
Gamma 5	563.23	0.084		
Gamma 6	1365.15	0.030		
Gamma 7	1167.94	0.018		
Gamma 8	475.35	0.015		
Gamma 9	1038.57	0.010		
Individual Isotope Total		2.228		0.849
Photon Fraction‡		0.724		0.276

* Decay data are from Eckerman et al. (1993).
† Cs-137's gamma photon emitted by a decay product, Ba-137m ($t_{1/2}$=153 s).
‡ Photon fraction is the ratio of the number of gamma photons emitted per transformation for each cesium radionuclide to the total number of emissions, and is based on equal activities of Cs-134 and Cs-137.

2.2.3. Field Calibration

Laboratory measurements using two discrete Cs-137 sources in a chest phantom resulted in a laboratory calibration factor of 0.179 nCi cpm^{-1} (6.6 Bq cpm^{-1}). However, when cesium is taken into the body it is uniformly distributed throughout the body tissues within a few days after uptake (ICRP, 1990) and it is consequently not modeled very well by using two discrete (point) sources. Additionally, in the field both Cs-134 and Cs-137 were found in approximately equal activities. Using only Cs-137 in the laboratory was inadequate for calibration of both Cs-134 and Cs-137 because the photons emitted by these two isotopes are different in both their number and energies as shown in Table 10.

Field calibration factors for Cs-134 and Cs-137 were determined using internal monitoring measurements from four people with detectable intakes measured on both the E-600/SPA-3 and ACCUSCAN II systems and who had nearly equal activities of detectable Cs-134 and Cs-137. The resulting calibration factors are 0.036 nCi cpm^{-1} for Cs-134 and 0.090 nCi cpm^{-1} for Cs-137. These calibration factors were thought to be more accurate than the laboratory calibration factor for Cs-137 using two discrete sources because they were calculated using measurements on actual people who were internally contaminated with both Cs-134 and Cs-137 that were distributed throughout their body tissues.

Only four persons with IM measurements met the technical criteria that were established for the cesium field calibration. The criteria used were:

- The fixed scanner system results had to show measurable amounts of radioactivity greater than the MDA for both Cs-134 and Cs-137,

- Both the fixed scanner (ACCUSCAN II or FASTSCAN) and the portable (E-600/SPA-3) systems had to result in measureable activity greater than the MDA,,
- The amounts of Cs-134 and Cs-137 activities measured on the fixed scanner should be such that the ratio of their activities is 1.0 ±0.25, which was derived from the air sample drawn on Barge YR-95 on March 15, 2011 (note, equal activities were assumed above to determine the photofractions listed in Table 10; Section 5.2 shows that the assumption is valid), and
- The data should not come from personnel who were scanned on April 12 or April 13, 2011, because the individuals scanned on these dates (the first two days of internal monitoring in Japan) may have been wearing contaminated clothing (see the discussion in Section 7.2).

The equations used to calculate the E-600/SPA-3 calibration factors for Cs-134 and Cs-137 are based on the principle that the average doses for the E-600/SPA-3 portable systems should be equal to the average doses obtained from the fixed scanner for the four measurements that met the technical criteria stated above. This is an obvious conclusion to reach because either system should be able to measure an individual and produce the same result. It is analogous to using two weight scales to independently measure the weight of a person. If the scales are calibrated properly then both should produce the same weight measurement. Furthermore, the weight measured should accurately reflect the true weight of the individual. Since the fixed scanner was rigorously calibrated to a national standard, the activity measurement made by the fixed scanner was accurate. Equation 1a immediately below shows the final form of the equation that was used to calculate the Cs-134 calibration factor, based on equating average doses from the fixed scanner and portable instrument. The derivation for Equation 1a is shown in Appendix F.

$$\overline{CF}_{Cs-134\ E600} = \frac{\overline{A}_{Cs-134\ Fixed}}{PF_{Cs-134} \times \overline{Net}_{E600}} \qquad (1a)$$

where:

$\overline{CF}_{Cs-134\ E600}$	=	Average Cs-134 calibration factor for E-600/SPA-3 (nCi cpm^{-1} or Bq cpm^{-1})
$\overline{A}_{Cs-134\ Fixed}$	=	Average Cs-134 activity as determined by the four fixed system scans used (Bq or nCi)
PF_{Cs-134}	=	Photon fraction for Cs-134 from Table 10 (value = 0.724, unitless)
$\overline{Net}_{E600}$	=	Average net count rate for the four E-600/SPA-3 measurements used (cpm)

Similarly, Equation 1b has been derived for Cs-137:

$$\overline{CF}_{Cs-137\ E600} = \frac{\overline{A}_{Cs-137\ Fixed}}{PF_{Cs-137} \times \overline{Net}_{E600}} \qquad (1b)$$

where:

$\overline{CF}_{Cs-137\ E600}$	=	Average Cs-137 calibration factor for E-600/SPA-3 (nCi cpm^{-1} or Bq cpm^{-1})
$\overline{A}_{Cs-137\ Fixed}$	=	Average Cs-137 activity as determined by the four fixed system scans used (Bq or nCi)
PF_{Cs-137}	=	Photon fraction for Cs-137 from Table 10 (value = 0.276, unitless)
$\overline{Net}_{E600}$	=	Average net count rate for the four E-600/SPA-3 measurements used (cpm)

Table 11 displays all the relevant measurements, DCs, IRFs, and calculated values from the four pairs of measurements that were used to calculate the E-600/SPA-3 Cs-134 calibration factor. All four pairs of measurements shown in Table 11 were made 31 days after the estimated date of intake. For discussion purposes each column has been labeled with a number and some cells have been shaded to aid in the clarity of the presentation. Columns with the same number contain the same information and have the same color of shading. Green-shaded cells indicate measurement values. Yellow-shaded cells indicate calculated doses. Pink-shaded cells indicate DC and IRF values. Rows in columns (1) and (10) are labeled with a number and the letter "a" or "b", representing paired measurements on the same individual with "a" for measurements taken with the fixed scanner and "b" for measurements taken with the E-600/SPA-3 portable instrument pair. The steps labeled 1 thru 4 and the columns (1) thru (20) have been laid out in logical order and will lead the reader through the calculation of the Cs-134 calibration factor and resulting doses. Each step is explained in its own paragraph below. The reader may want to refer to the discussions of DCs and IRFs in Section 3, and also review the dose calculation equations presented in Section 5, in order to help understand the discussion below.

In Step 1:

- Columns (1) through (9), provide the fixed scanner calculations for the committed effective dose [E(τ)] [column (5)], the E(τ) from all assumed nuclides in the environment [column (7)], and the thyroid committed equivalent dose [H_T,τ] from all assumed nuclides in the environment [column (9)].
- Column (3) is the Cs-134 DC for an adult from ICRP Publication 71 (1995) and column (4) is the IRF for cesium at 31 days from Potter (2000).
- Measured Cs-134 activity values from the fixed scanner are listed in column (2); these are multiplied by the DC in column (3) and divided by the IRF in column (4) to obtain the Cs-134 E(τ) in column (5).
- These values are multiplied by the value in column (6), which is the ratio of E(τ) from all assumed nuclides to the E(τ) from Cs-134 (see e.g., Table 19), to obtain the values in column (7), which are E(τ) dose values from all assumed nuclides in the environment.

- These values are multiplied by the value in column (8), which is the ratio of the thyroid H_T,τ to the $E(\tau)$ for all nuclides (see e.g., Table 19), to obtain the values in column (9), which are H_T,τ dose values from all assumed nuclides in the environment.

In Step 2: columns (10) through (16), provide the calculation of the Cs-134 calibration factor [column (16)].

- The net E600/SPA-3 chest measurement in cpm [column (13)] is calculated by subtracting the chest background measurement [column (12)] from the gross chest measurement [column (11)].
- The average net chest measurement is calculated at the bottom of column (13).
- From Equation 1a above, the E600/SPA-3 Cs-134 calibration factor (nCi cpm^{-1}) is obtained by dividing the average fixed measured Cs-134 activity shown at the bottom of column (15) by the Cs-134 photon fraction in column (14) and the average chest measurement at the bottom of column (13).
- The calibration factor is shown at the bottom of column (16) with a value of 0.0357 nCi cpm^{-1}.

In Step 3, columns (10), (13), (14), (16), (17), (3), (4) and (18) provide the E600/SPA-3 calculation for $E(\tau)$ [column (18)].

- The net chest count rate [column (13)] is first multiplied by the photon fraction [column (14)] and the calibration factor [column (16)] to obtain the net measured activity [column (17)].
- $E(\tau)$ [column (18)] is then obtained by dividing the net activity [column 17] by the IRF [column (4)] and multiplying by the DC [column (3)].

In Step 4, columns (10), (18), (6), (19), (8), and (20) provide the E600/SPA-3 calculations for $E(\tau)$ [column (19)] and the thyroid committed equivalent dose [H_T,τ] from all assumed nuclides in the environment [column (20)]. This is accomplished in a manner analogous to that shown in the latter portion of Step 1 described above for the fixed scanner.

Since the derivation of Equation 1a started by equating average doses from the pairs of measurements from the fixed scanner and portable instrument, it is not surprising that the average doses shown at the bottom of columns (5), (7), and (9) from the fixed scanner measurements are equal to the average doses shown at the bottom of columns (18), (19), and (20) from the E600/SPA-3 measurements. However, the individual paired doses do vary somewhat between the fixed scanner and E600/SPA-3 values.

Table 11. Spreadsheet showing values used in the calculation of the Cs-134 calibration factor

	Col (1)	Col (2)	Col (3)	Col (4)	Col (5)	Col (6)	Col (7)	Col (8)	Col (9)
STEP 1.	Fixed Record Number	Fixed Measured Wholebody Cs-134 (nCi)	Cs134 DC Adult ICRP 71 (mrem nCi $^{-1}$)	Cs134 IRF (31 days) Adult	Fixed E(τ) Cs-134 (mrem)	Ratio E(τ) All / E(τ) Cs-134 from Table 17	Fixed E(τ) for All (mrem)	Ratio $H_T(\tau)$ / E(τ) from Table 17	Fixed Thyroid $H_T(\tau)$ for All (mrem)
	1a	23.90	0.024	0.348	1.7	14.83	25	16.8	417
	2a	18.81	0.024	0.348	1.3	14.83	20	16.8	328
	3a	20.24	0.024	0.348	1.4	14.83	21	16.8	353
	4a	10.28	0.024	0.348	0.7	14.83	11	16.8	179
	Average	18.31			1.28		19		320

	Col (10)	Col (11)	Col (12)	Col (13)	Col (14)	Col (15)	Col (16)
STEP 2.	E600 Record Number	E600 Chest Gross (measured) (cpm)	E600 Chest Bkg (measured) (cpm)	E600 Chest Net (G-Bkg) (cpm)	Cs-134 Photofraction from Table 10	Fixed Average Measure Wholebody Cs-134 (nCi)	E600 Cs-134 Calibration Factor Eq 1a (nCi cpm^{-1})
	1b	6410	5902	508			
	2b	6450	5902	548			
	3b	6800	5902	898			
	4b	6780	5902	878			
			Average	708	0.724	18.31	0.0357

	Col (10)	Col (13)	Col (14)	Col (16)	Col (17)	Col (3)	Col (4)	Col (18)
STEP 3.	E600 Record Number	E600 Chest Net (G-Bkg) (cpm)	Cs-134 Photon Fraction from Table 10	E600 Cs-134 Calibration Factor Eq 1a (nCi cpm^{-1})	E600 Chest Net (nCi)	Cs134 DC Adult ICRP 71 (mrem nCi $^{-1}$)	Cs134 IRF (31 days) Adult	E600 E(τ) Cs-134 (mrem)
	1b	508	0.724	0.0357	13	0.024	0.348	0.9
	2b	548	0.724	0.0357	14	0.024	0.348	1.0
	3b	898	0.724	0.0357	23	0.024	0.348	1.6
	4b	878	0.724	0.0357	23	0.024	0.348	1.6
	Average							1.28

	Col (10)	Col (18)	Col (6)	Col (19)	Col (8)	Col (20)
STEP 4.	E600 Record Number	E600 E(τ) Cs-134 (mrem)	Ratio E(τ) All / E(τ) Cs-134 from Table 17	E600 E(τ) for All (mrem)	Ratio $H_T(\tau)$ / E(τ) from Table 17	Fixed Thyroid $H_T(\tau)$ for All (mrem)
	1b	0.9	14.83	14	16.8	229
	2b	1.0	14.83	15	16.8	247
	3b	1.6	14.83	24	16.8	405
	4b	1.6	14.83	24	16.8	396
	Average	1.28		19		320

2.2.4. Measured Instrument Variability

To determine the E-600/SPA-3 instrument variability, a series of measurements was taken on April 18, 2011, at the Atsugi NAF IM station. Three E-600/SPA-3 instrument sets were used to measure background rates for the thyroid, chest and free-in-air condition (FAC) at a minimum of three different times of the day, using the same person for all measurements to isolate only changes in response due to the variability between instruments. From the data in Table 12, the average coefficients of variation (CV) were calculated using Equation 2. CV values for the thyroid and chest counts were calculated to be 2.3 percent and 1.9 percent, respectively; the average of these two values is 2.1 percent (rounded to 2 percent)

$$CV = \frac{\sigma}{\mu} \tag{2}$$

where:

CV	=	Coefficient of variation (unitless), which can be expressed as a percentage by multiplying by 100
σ	=	Standard deviation of the count-rate distribution (cpm)
μ	=	Mean of the count rate distribution (cpm)

Table 12. Calculation of the coefficient of variation for chest and thyroid background measurements

E-600/SPA-3 Set	Start Time of Measurement*	Background Measurement Count Rate† (cpm)		
		Chest	Thyroid	FAC
3355/2436	0705	6190	6290	
	0800	-	-	6620
	0910	-	-	6480
	0950	-	-	6570
	1030	-	-	6480
	1102	-	-	6610
	1305	5920	6110	
	1354	-	-	6400
	1535	5970	6130	-
	Average‡	6027	6177	6527
	%CV	2.4%	1.6%	1.3%
	(Bkg/FAC)×100	92.3%	94.6%	100%
3198/2428	0702	5910	5980	-
	0758	-	-	6210
	0827	-	-	6360
	0924	-	-	6230
	1003	-	-	6290
	1052	-	-	6240
	1301	5770	5780	
	1350	-	-	6080
	1422	-	-	6360
	1550	5660	5780	
	Average‡	5780	5847	6235
	%CV	2.2%	2.0%	1.5%
	(Bkg/FAC)×100	92.7%	93.8%	100%
3302/2430	0705	5930	5970	-
	0805	-	-	6230
	1014	-	-	6250
	1056	-	-	6330
	1240	5810	5820	-
	1401	-	-	6160
	1514	5840	5600	-
	Average‡	5860	5797	6243
	%CV	1.1%	3.2%	1.1%
	(Bkg/FAC)×100	93.9%	92.9%	100%
From all 3 Sets	Average CV	1.9%	2.3%	1.3%

* All chest and thyroid measurements were taken during a 20-minute period; all free-in air (FAC) measurements were taken during a 10-minute period.

† Background (Bkg) count rates are average values during the counting period as calculated by and displayed on the E-600.

‡ Values in these rows are averages for each E-600/SPA-3 set

§ "-" means no measurement taken.

2.2.5. Critical Level and Minimum Detectable Activity

The Critical Level is the value at which a decision can be made that a positive quantity of a radioisotope is present. The MDA is the smallest amount of radioactivity (or cpm in the E600/SPA-3 case) that can be detected with a given [high] degree of confidence. At the decision level, there is only 50-50 chance that the activity will be identified as such (assuming normal distribution of counts). An OT RIMIS administrative decision was made to use the MDA as the comparative value for measurements, i.e., to report measurement results as either above or below the MDA. The practical MDA above background has been calculated based on a 97.5 percent confidence level, meaning that there is a 97.5 percent probability of avoiding both a false positive error and a false negative error. At this confidence level, distribution values for both error probabilities are set at two standard deviations, indicated by 2σ in Figure 15. The decision level value ($L_{Critical}$) shown in Figure 15 is the value at which the decision can be made that the measurement represents a net count rate (or activity if used with a calibration factor).

The equations used for MDA and $L_{Critical}$ calculations are shown in Equations 3 and 4, which were derived based on the relations shown in Figure 15.

$$MDA = Bkg \times \frac{(4 \times CV)}{(1 - 2 \times CV)} \tag{3}$$

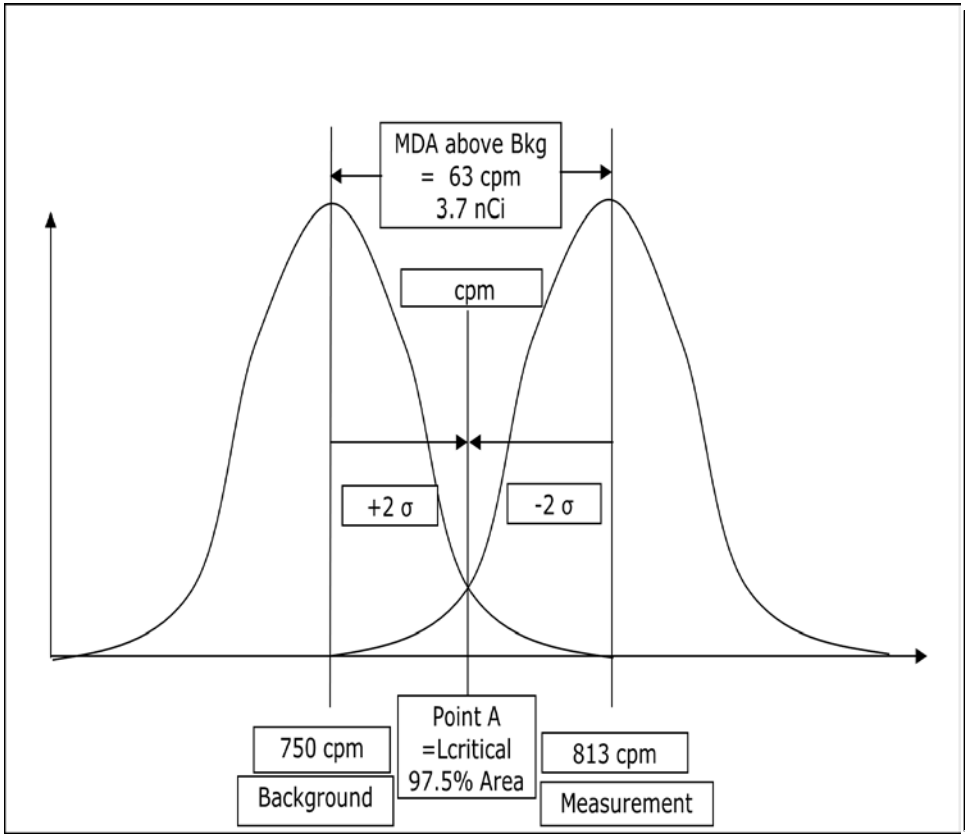
$$L_{Critical} = 2 \times CV \times Bkg \tag{4}$$

where:

MDA	=	Minimum detectable activity (count rate) above background (cpm)
Bkg	=	Background activity (count rate) (cpm)
CV	=	Coefficient of variation (unitless)
$L_{Critical}$	=	Critical (or Decision) level (count rate) (cpm)

As explained in Section 4.2, it was necessary to take background measurements for the portable instruments with the SPA-3 probe held on the throat, and chest or back of a person who was specifically identified for this purpose.

The background count rates measured on the thyroid and chest at Atsugi NAF resulted in an MDA of 2.7–3.0 nCi (~100 Bq) for iodine and 28–31 nCi (~1,100 Bq) for cesium.



E-600 MDA above Background for various Backgrounds.			
CV (Std/ mean)	Bkg (cpm)	MDA Above Bkg (cpm)	MDA Above Bkg (nCi)
0.02	500	42	3
0.02	750	63	4
0.02	1000	83	5
0.02	2000	167	10
0.02	4000	333	20
0.02	6000	500	30
E-600 MDA above Background for various CVs.			
CV (Std/ mean)	Bkg (cpm)	MDA Above Bkg (cpm)	MDA Above Bkg (nCi)
0.01	750	31	2
0.02	750	63	4
0.03	750	96	6
0.04	750	130	8
0.05	750	167	10
0.06	750	205	12

Figure 15. Example of practical MDA above background for E-600/SPA-3 (chest)

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Section 3.

Radiological Properties and Biokinetics of Relevant Radionuclides

3.1 Dose Coefficients

The DCs used in calculations of committed effective dose and committed equivalent dose were taken from ICRP databases. Specifically, the ICRP electronic database that contains DCs for workers and members of the public was used (ICRP, 2001). That database provides DCs for the following age categories (with recommended age ranges): 3 mo (birth to 1 y), 1 y (>1 y to 2 y), 5 y (>2 y to 7 y), 10 y (>7 y to 12 y), 15 y (>12 y to 17 y), and adults (>17y). Age-dependent inhalation DCs were selected for particles with a particle size distribution represented by an activity median aerodynamic diameter of 1 μm and absorption Type F (Fast). The ICRP provided the following summary of this database of DCs as they compare to previous ICRP compilations:

> The results are essentially the same as the latest ICRP advice given in Publications 68 (workers) and 72 (members of the public). The database extends the results given in these Publications *[sic]* to include DCs for ten aerosol sizes and for ten times after intake. (ICRP, 2001)

3.2 Biokinetics of Iodine and Cesium in the Human Body

The radionuclides measured during the OT RIMIS program were I-131, Cs-134, and Cs-137. Biokinetics account for the biological behavior of substances taken into the body by inhalation, ingestion, or other routes of intake. Various biokinetic models have been developed and documented in several ICRP publications and validated with empirical data taken from both human and animal studies (e.g., ICRP, 1979; ICRP, 1980; ICRP, 1991; ICRP, 1994a; ICRP, 1994b). For the OT RIMIS program, I-131, Cs-134, and Cs-137 were measured as described in Section 2. The OT RIMIS measurements accounted for any activity that could be detected above the MDA without regard to the route of entry to the body. The elimination of a substance from the body is typically measured by a biological half-time, i.e., the time required for the body to eliminate through biological processes one-half of the substance that was taken into the body. Biological half-time is analogous conceptually to the radioactive half-life for radioactive decay in that both are the time required for a quantity of material to be reduced to one-half of its initial value, either biologically or by radioactive decay. The effective half-life accounts for both biological half-time and radioactive half-life and is calculated with Equation 5.

$$T_{EFF} = \frac{T_b \times T_p}{T_b + T_p} \tag{5}$$

where:

T_{EFF}	=	Effective half-life (e.g., days)
T_b	=	Biological half-time (e.g., days)
T_p	=	Radioactive half-life (e.g., days [must be the same units as T_b])

3.2.1. Iodine

The following relevant description of the human biokinetic model for iodine is provided in ICRP Publication 78 (ICRP, 1997):

> It is assumed that of iodine reaching blood a fraction of 0.3 is accumulated in the thyroid gland and 0.7 is excreted directly in urine. The biological half-time in blood is taken to be 0.25 days. Iodide incorporated into thyroid hormones leaves the gland with a half-time of about 80 days and enters other tissues where it is retained with a half-time of 12 days. Most iodide (80%) is subsequently released and is available in the circulation for uptake by the gland and urinary excretion; the remainder (20%) is excreted in faeces in organic form. The biokinetic model for iodine assumes that 0.3 is taken up by the thyroid and the remainder is excreted in urine. In fact, there are relatively large variations, depending on many parameters and these are especially important in case of thyroid dysfunctions. For example, current uptake values for a European euthyroid adult are in the range 0.20±0.25. Pathological states of the thyroid may result in uptake values from 0±0.05 (blocked thyroid) to more than 0.5. Hypothyroid adults have a low thyroid uptake, but a prolonged excretion, resulting in a thyroid dose a little larger than normal. On the contrary, hyperthyroid adults exhibit a shorter iodine half-time in the thyroid and therefore have a smaller thyroid dose. When such cases are suspected, then individual values should be introduced in the dose calculation, especially in case of accidental exposure, where a precise assessment is needed.

Using the radioactive half-life for I-131 of 8.04 d (ICRP, 1997) and the IRF values from Potter (2002) discussed in Section 3.3 of this report, the biological half-time for iodine in the body can be calculated to be 104.8 d.

3.2.2. Cesium

Following ingestion or inhalation, cesium will be uniformly distributed in the body fluids and tissues within a few days for most cesium compounds resulting from a reactor accident with fission product release. The biological half-time for cesium in the body for OT RIMIS was conservatively taken to be 109.9 d for adults based on radioactive half-lives for Cs-134 and Cs-137 of 2.06 y and 30.0 y, respectively, and the IRF values in Potter (2002). However, biological half-times for males and females may be different, according to ICRP Publication 78 (ICRP, 1997), which states:

> Systemic caesium is taken to be distributed uniformly throughout all body tissues; 10% of activity is assumed to be retained with a biological half-time of 2 days (A) and 90% with 110 days (B) (Table A.7.1.). For females however, the half-time for

compartment B is significantly less than for males (Publication 56, ICRP, 1990). There is also evidence that in some countries the mean biological half-time of caesium in adult males is shorter than 110 days (Suomela, 1971; Hasanen and Rahola, 1971).

The biological half-times and radioactive half-lives used in OT RIMIS calculations are shown in Table 13. Note, the decay constants are defined as the natural logarithm of 2 [ln(2)] divided by either the radioactive half life or the biological half- time.

Table 13. Biological and radioactive decay characteristics of cesium and iodine isotopes

Radionuclide	Effective Half-life (d)	Biological Half-time (d)	Radioactive Half-life (d)	Effective Decay Constant (d^{-1})	Biological Decay Constant (d^{-1})	Radioactive Decay Constant (d^{-1})
Cs-137	108.78	109.9	10,957	6.372×10^{-3}	6.309×10^{-3}	6.326×10^{-5}
Cs-134	95.87	109.9	752.4	7.230×10^{-3}	6.309×10^{-3}	9.212×10^{-4}
I-131	7.47	104.8	8.04	9.283×10^{-2}	6.614×10^{-3}	8.621×10^{-2}

3.3 Intake Retention Fraction

To estimate the intake of a radionuclide from IM results, the expected fraction of an intake remaining in the organ or whole body must be determined. The expected time-dependent fraction remaining can be expressed as an intake retention function, i.e., the expected fraction remaining as a function of time after intake. The value of the function at a specific time is referred to in this report as the Intake Retention Fraction (IRF).

3.3.1. Adult Intake Retention Fractions

Adult inhalation IRF values were taken from Potter (2002), assuming absorption Type F materials that are readily absorbed into body fluids from the respiratory tract. The IRF values for iodine and cesium are taken from Table B35, page 641 and Table B36, page 642 of Potter (2002). The IRF values used for iodine are those for "Thyroid" in Table B35 because the OT RIMIS I-131 measurements were taken at the throat over the thyroid, and thus activity in the thyroid was measured. The IRF values used for cesium are those for "WB" in Table B36 because the OT RIMIS cesium measurements were taken on the chest or back and recorded counts from the whole body, and thus activity (and retention) in the whole body was measured. The tables in Potter (2002) list IRF values for non-radioactive iodine and cesium and must be corrected for radiological decay as shown in Equation 6.

$$IRF_x(t) = IRF_{X,x}(t) \times exp\left(-\frac{ln(2) \times t}{T_{r,x}}\right) \quad (6)$$

where:

$IRF_x(t)$	=	IRF at time t for radionuclide x corrected for radioactive decay (unitless)
$IRF_{X,,x}(t)$	=	IRF at time t for stable element X of which x is an isotope (unitless)
t	=	Time after intake (d)
exp	=	The exponential function e^x, written as exp(x)
$T_{r,x}$	=	Radioactive half-life of radionuclide x (d)

Models used in Potter (2002) for the calculation of the IRFs were those used in determining the dose coefficients in ICRP Publication 68. These models include the human respiratory tract model presented in ICRP Publication 66 (ICRP, 1994a) and the gastrointestinal tract model presented in ICRP Publication 30 (ICRP, 1979; ICRP, 1980).

Tables B35 and B36 of Potter (2002) provide discrete IRF values at 48 post-intake times from 0.25 d through 30,000 d. To obtain values between those listed, an exponential fit was done on the values listed. Equations 7a–7c are the resulting equations for calculating radioactive decay-corrected IRF values for the three relevant radionuclides in the program, obtained from the exponential fit with the time, t, expressed in days (d).

$$IRF_{I-131}(t) = 0.141366 \times exp(-0.092826 \times t) \quad (7a)$$

$$IRF_{Cs-134}(t) = 0.43546 \times exp(-0.007230 \times t) \quad (7b)$$

$$IRF_{Cs-137}(t) = 0.43546 \times exp(-0.006372 \times t) \quad (7c)$$

3.3.2. Age Dependent Intake Retention Fraction for Children

Age dependent IRF values are not currently available from the literature. The distribution and retention information from ICRP (1990) was used to calculate IRF values from intakes by inhalation for children for the five age categories as defined in ICRP Publication 56 as: 3 mo (birth to 1 y), 1 y (>1 y to 2 y), 5 y (>2 y to 7 y), 10 y (>7 y to 12 y), 15 y (>12 y to 17 y).

3.3.2.1 Iodine

The distribution and retention information from ICRP Publication 56 (ICRP, 1990) task group 2, Section 7, pages 45–52 was used to determine IRF values for the five children's age categories discussed above. ICRP Publication 56 adopted the basic three compartment model in ICRP Publication 30 (ICRP, 1979) with a number of modifications to describe the biokinetics of iodine in adults and children after its entry into the blood. This model differs from that used in ICRP Publication 53 (ICRP, 1988), which does not allow for recycling of iodine to the thyroid gland following the intake of iodine-labeled radiopharmaceuticals. The consideration of recycling is only necessary for long-lived iodine isotopes.

Retention data for stable iodine are largely obtained from studies using I-131. Because of the short radioactive half-life of this isotope (8.04 d), retention in the thyroid gland is normally

followed for about two weeks, which is too short a time to enable resolution of the radioactive decay and biological elimination functions as shown in ICRP Publication 56 and originally taken from Fell and Adams (1978). As a consequence many investigators report a single exponential clearance from the thyroid gland; the half-time for this retention is called the "apparent" half-time in this report. For OT RIMIS calculations of the retention fraction, the single exponential form of the retention function for stable iodine shown by Equation 8 was used.

$$R(t) = C \times exp\left(\frac{-ln(2) \times t}{T_{app}}\right) \quad (8)$$

where:

$R(t)$ = Fractional retention of stable iodine in the thyroid gland, as a function of time (t) (unitless)

C = A constant used to match the conditions at a time of 1 day (unitless)

$ln(2)$ = natural logarithm of 2

T_{app} = Apparent half-time for iodine (d) in the thyroid

The apparent half-times (T_{app}) recommended in ICRP (1990) for various age categories are shown in Table 14.

Table 14. Apparent half-times for iodine in the thyroid for various age categories

Age Category	Apparent Half-Time (d)*
3-month	15
1-year	20
5-year	30
10-year	70
15-year	80
Adult	91

* ICRP (1990), Table 7-1.

The retention function shown in Equation 8 does not account for radioactive decay. The intake retention fraction with the inclusion of radioactive decay and the biological removal term of Equation 8 is shown in Equation 9.

$$IRF(t) = C \times exp\left(\frac{-ln(2) \times t}{T_{app}}\right) \times exp\left(\frac{-ln(2) \times t}{T_{r,I131}}\right) \quad (9)$$

where:

$IRF(t)$ = Intake retention fraction for radioiodine in the thyroid gland, as a function of time (t) (unitless)

C = A constant used to match the conditions at a time of 1 day (unitless)

$ln(2)$ = natural logarithm of 2

T_{app} = Apparent half-time for iodine (d)

$T_{r,I131}$ = Radioactive half-life of I-131 (d)

The values of C in Equation 9 were calculated using the values of T_{app} listed in Table 14 and with the assumption that the IRF for each age category was equal to 0.120, which is the value for the thyroid for adults taken from Potter (2002). The resulting values of C are listed in Table 15.

Table 15. Calculated values of *C* for children's are categories

Age Category	Value of C
3-month	0.136
1-year	0.135
5-year	0.133
10-year	0.132
15-year	0.131

Application of Equation 9, the T_{app} listed in Table 14 and the values for C for each age category result in the IRF values shown in Figure 16. The IRF values are higher for older ages for all times after intake and result in the 3-month old category showing the most rapid elimination (lowest retention). This is consistent with biological half times for iodine, which decrease with decreasing age (e.g., Zanzonico, 2000). There is not a great deal of difference (i.e., not more than a factor of three in the first 30 days after intake) in the IRF values among age groups. To simplify the OT RIMIS calculations during deployment, adult IRF values were used for all age groups. It was later shown that there were no child iodine activity measurements greater than MDA and therefore using adult IRF values had no effect on child doses.

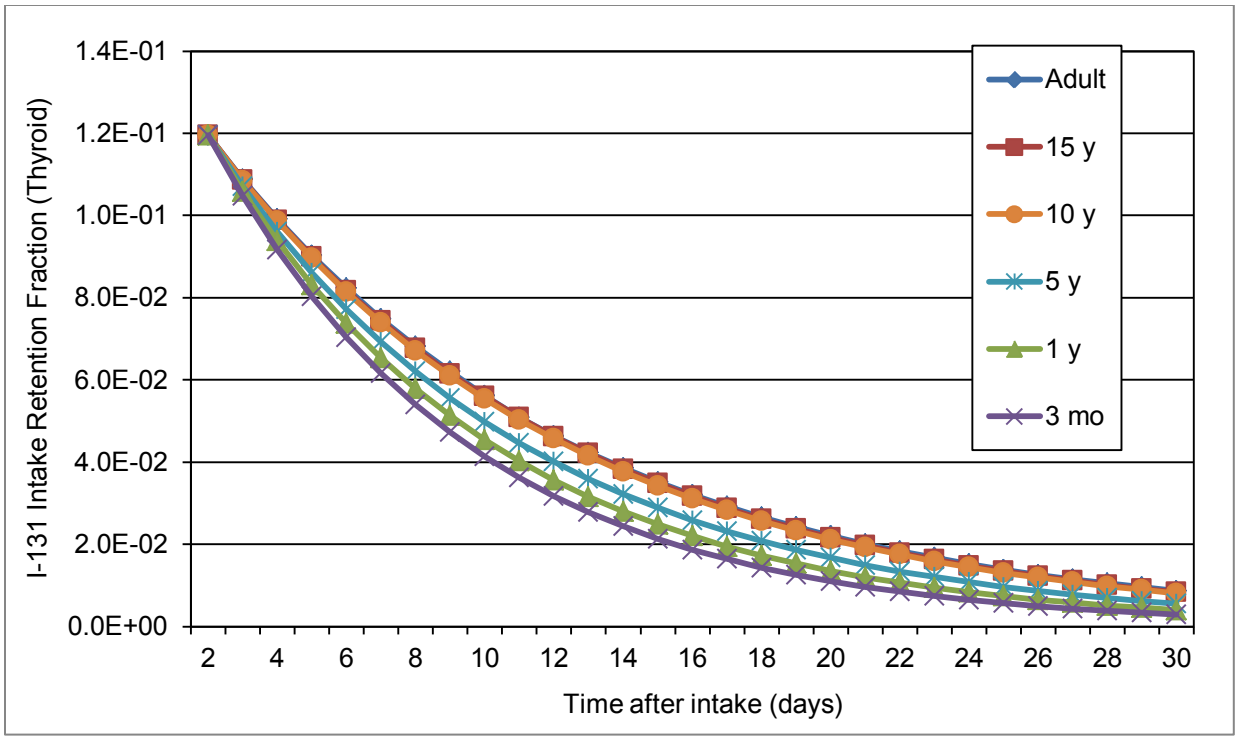

Figure 16. I-131 intake retention functions for inhalation for various age categories

3.3.2.2 Cesium

The distribution and retention information from ICRP (1990), task group 2, Section 8, pages 53–58 was used to determine IRF values for the five children's categories discussed previously. ICRP Publication 56 contains the following statement regarding distribution and retention of cesium (pg 53):

> Cesium behaves similarly to potassium after its entry into the blood, being accumulated by all body tissues. Higher concentrations of cesium have been reported for muscle than for other tissues, but differences in concentration between tissues are relatively small. It is therefore assumed for the purpose of dosimetry that cesium is uniformly distributed throughout the body tissues after its clearance from the blood (Harrison et al., 1963; ICRP,1979; Müller and Scheffer, 1982).

ICRP Publication 30 (ICRP, 1979) contains a recommended biological retention function, $R(t)$, for cesium in the form of the sum of two exponential components as shown by Equation 10.

$$R(t) = F_A \times exp\left(\frac{-ln(2) \times t}{T_A}\right) + F_B \times exp\left(\frac{-ln(2) \times t}{T_B}\right) \qquad (10)$$

where:

$R(t)$ = Whole body fractional retention function for stable cesium, as a function of time (t) (unitless)

F_A = Fraction of cesium in body compartment A (unitless)

F_B = Fraction of cesium in body compartment B (unitless)

T_A = Biological half-time in body compartment A (d)

T_B = Biological half-time in body compartment B (d)

Recommended values of F_A, F_B, T_A, and T_B are reproduced from ICRP (1990) in Table 16.

Table 16. Biokinetic information for the cesium retention calculation

Age	f_1	Distribution in Total Body (%)		Biological Half-time in Total Body (d)		Weighted Half-time (d)
		Comp. A*	Comp. B	Comp. A	Comp. B	
3 months	1	0	100	0	16	16.0
1 year	1	0	100	0	13	13.0
5 years	1	45	55	9.1	30	20.6
10 years	1	30	70	5.8	50	36.7
15 years	1	13	87	2.2	93	81.2
Adult	1	10	90	2	110	99.2

* A urinary-to-fecal excretion ratio of 4:1 is assumed for cesium that has entered the transfer compartment.

The retention function shown in Equation 10 does not account for radioactive decay. The intake retention fraction with the inclusion of radioactive decay and the biological removal terms of Equation 10 is shown in Equation 11. To expedite the calculation a bias factor, B, is used to match boundary conditions for measured values during the first few days.

$$IRF(t) = B\left[F_A \times exp\left(\frac{-ln(2) \times t}{T_A}\right) + F_B \times exp\left(\frac{-ln(2) \times t}{T_B}\right)\right] exp\left(\frac{-ln(2) \times t}{T_{r,Cs}}\right) \qquad (11)$$

where:

$IRF(t)$ = Whole body fractional retention fraction for a specific cesium radionuclide (i.e., Cs-134 or Cs-137) as a function of time (t) (unitless)

B = B is a bias factor used to match the value at 1 day.

F_A = Fraction of cesium in body compartment A (unitless)

F_B = Fraction of cesium in body compartment B (unitless)

T_A = Biological half-time in body compartment A (d)

T_B = Biological half-time in body compartment B (d)

$T_{r,Cs}$ = Radioactive half-life for a radioisotope of cesium (e.g., Cs-134, Cs-137, etc.).

The values of *C* in Equation 11 were calculated using the values listed in Table 16 and with the assumption that the IRF for each age category was equal to 0.596, which is the value for the whole body for adults taken from Potter (2002). The resulting values of *C* are listed in Table 17.

Table 17. Calculated values of *B* for children's age categories

Age Category	Value of *B*
3-month	0.540
1-year	0.568
5-year	0.546
10-year	0.532
15-year	0.503

Application of Equation 11, the values from Table 16 and the values for constant *B* from Table 17 result in the IRF values for Cs-137 shown in Figure 17. A similar calculation was done for Cs-134 with similar results. The age-dependent IRF values calculated using Equation 11 were used in the OT RIMIS calculations.

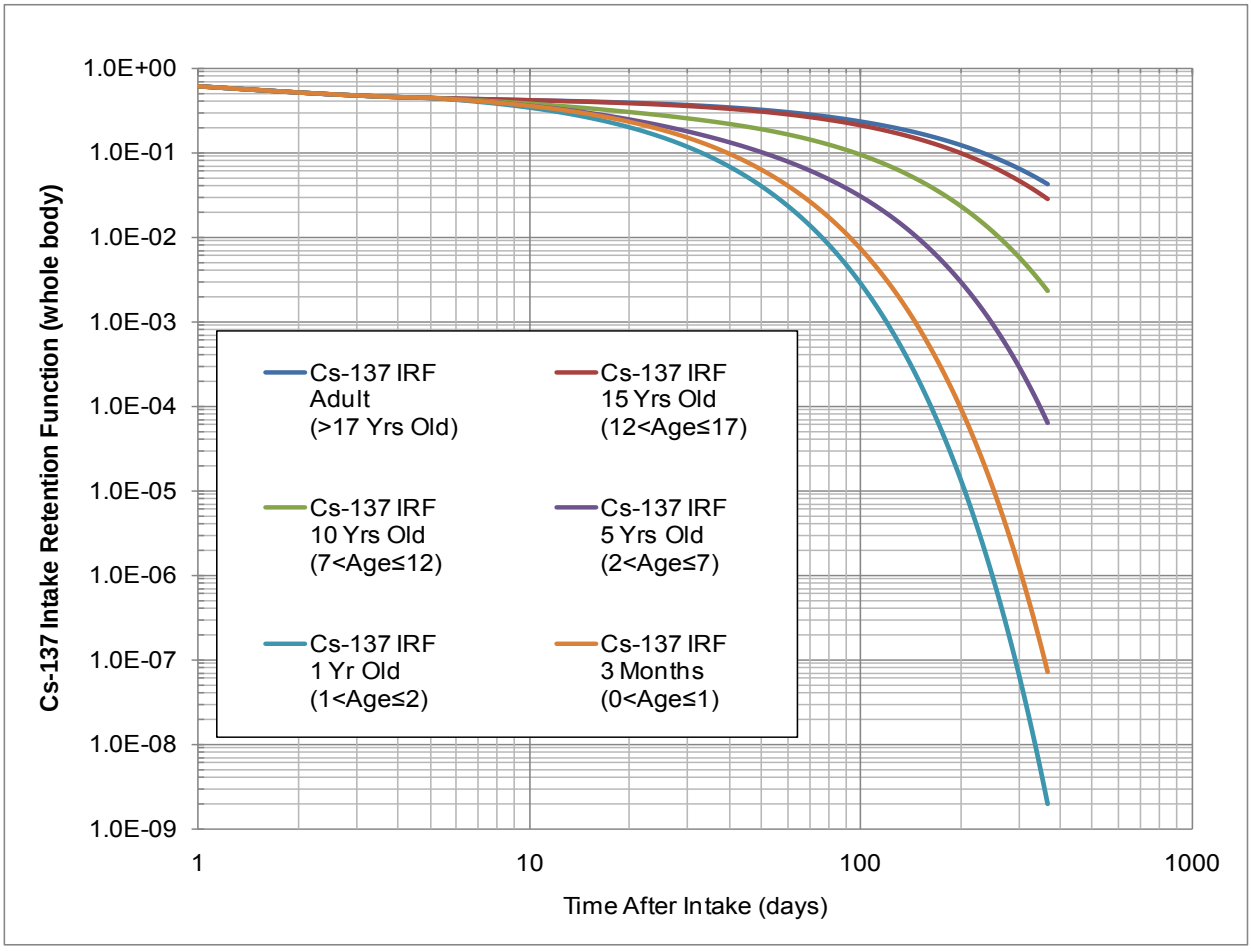

Figure 17. Cs-137 inhalation intake retention fractions for various age categories

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Section 4.

Background Measurements

Ionizing radiation exists in most environments as a result of emissions from radioactive materials in nature, from cosmic rays, and from various manufactured items or systems. This persistent radiation, known as background radiation, must be taken into account when measuring radioactivity in people as is done in IM. If not properly taken into account, background radiation can lead to inaccurate measurements of activity in the body, such as either false positives or false negatives. Because background radiation could vary over time, and with day-to-day changes in the measurement systems, a program for monitoring the background at locations conducting IM measurements was absolutely essential to obtaining accurate measurements with good quality control. Details of the process for background monitoring during IM are discussed for the fixed and portable instruments used.

4.1 Fixed Systems

Background activity measurements for FASTSCAN and ACCUSCAN II systems were done in accordance with standard operating procedures as given by the procedures manual from the manufacturer and used by U.S. Naval shipyards. The procedures specify background checks before any IM procedure, every 8 hours during a series of IM measurements, at least one every week during periods of no IM, and a monthly environmental background count. (PSNS, 2012a)

4.2 Portable Instrument Systems

Background measurements for thyroid and chest were taken using a person with no measurable internal activity from FDNPS, designated as a "clean human phantom." The person was declared "certified" as a clean human phantom after they had a fixed scan, which resulted in no positive activity results. Background counts for the E-600/SPA-3 were always taken using a person certified to be clean from iodine or cesium contamination in the same manner with respect to position and number of instruments as the person being measured. For each instrument, background counts were taken at the beginning and end of each 8-hour shift. Background counts were taken for FAC, thyroid, and chest or back using an instrument holder as shown in Figure 11 and Figure 12. Once background counts were taken, any change in the position of the probe was followed by a new background count.

As discussed in Section 2.2.4 and calculated with the values in Table 12, there was a CV of about 2 percent between instruments or between times of the day for the same instrument. As described earlier, the level of background activity (or cpm) affects the MDA (see Figure 15 and Equation 3).

The clean human phantom affected the background count in two opposing ways; first, by acting as a radiation source from normal, naturally occurring radioactivity in the body (such as potassium-40), and second, by acting to shield non-phantom background radiation. The ratio in the throat, chest, or back measurement to the FAC measurement changed depending on the magnitude of the FAC background level. In low background areas (~600 cpm, typical for

locations onboard ships) the ratio of chest to FAC measurements was greater than unity, but in high background areas (~6,000 cpm) the ratio was less than unity. This observation shows that the clean human phantom acted as a radiation source at background levels up to about 3,000 cpm, and acted as a shield at background levels above about 3,000 cpm. Ratios from clean human phantom background measurements at 68 different locations and/or days are shown in Figure 18.

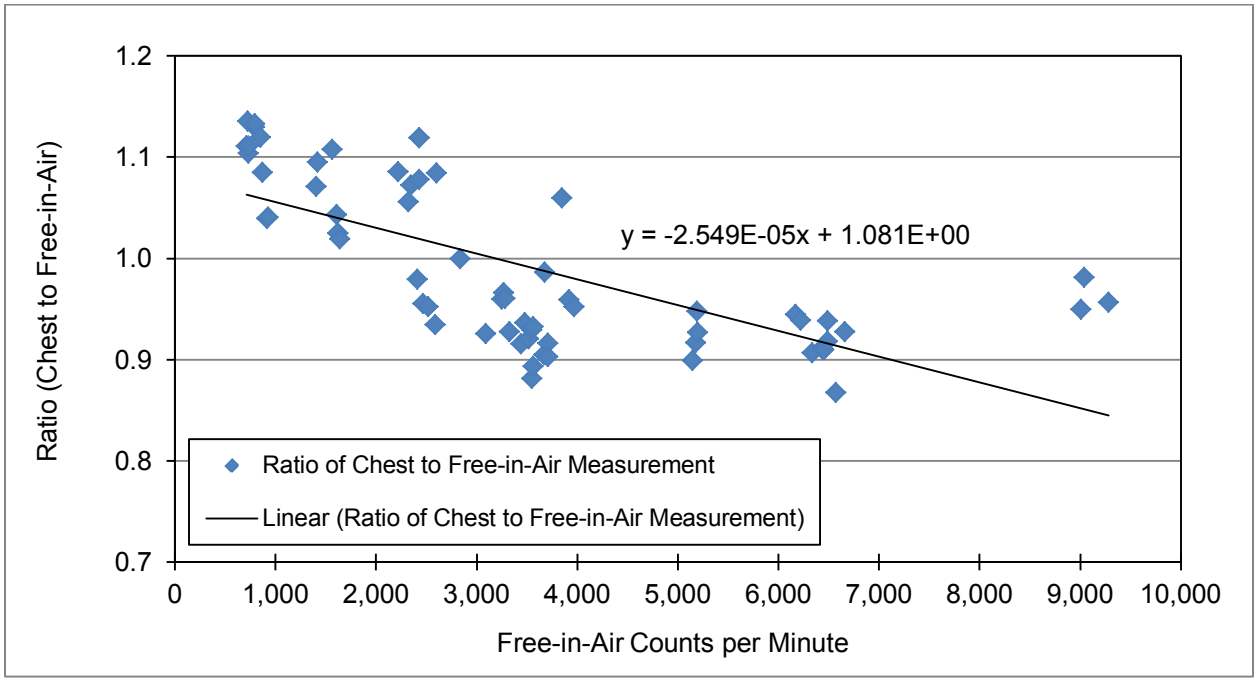


Figure 18. Ratios of background measurements (chest and free-in-air) for different locations

The line shown in Figure 18 is a linear fit of the data points to illustrate the approximate behavior of the ratio of chest to free-in-air count rates as a function of free-in-air background count rate.

The data shown in Figure 18 indicate, for the E600/SPA-3 portable instrument, it was necessary to measure the background on a person, rather than to measure background free-in-air. Further, just using a non-human phantom, such as an acrylic phantom, resulted in a slight over-estimate in activity in areas of background below 3,000 cpm since the person being measured would have at least a natural source inside them that would not be subtracted out with the use of the acrylic phantom background measurement. As supplemental information, the average amount of natural radioactivity in the body is shown in Table 18.

Uncertainty was introduced by using the clean human phantom concept because people vary in size causing different shielding effects to background radiation and also vary in the amount of naturally occurring radionuclides inside them. The variations in the people used as clean human phantoms during OT were empirically determined by analysis of the background measurements taken. To do this a CV was calculated for the ratio of chest to FAC background using 475 measurements from 22 instruments and 20 different clean human phantom persons.

Using a ratio normalizes the result to allow different instruments to be compared. A CV of 3.2 percent in the ratio was calculated.

Table 18. Naturally-occurring radionuclides in the human body

Radionuclide*	Mass	Activity
Uranium	90 µg	1.1 Bq
Thorium	30 µg	0.11 Bq
Potassium 40	17 mg	4.4 kBq
Radium	31 pg	1.1 Bq
Carbon 14	22 ng	3.7 kBq
Tritium	0.06 pg	23 Bq
Polonium	0.2 pg	37 Bq

* Source is Eckerman and Sjoreen (2003).

As discussed in Section 2.2.4 and calculated with the values in Table 12, there was a CV of about 2 percent between instruments or between times of the day for the same instrument. If it is assumed that the CV of 3.2 percent from the analysis of background data as discussed in the previous paragraph includes the 2 percent then just the component from using different people for clean human phantoms can be determined. Assuming the propagation of error in quadrature is appropriate then Equation 12 would apply.

$$\sigma_I^2 + \sigma_P^2 = \sigma_T^2 \tag{12}$$

where:

σ_I^2 = Instrument CV (2 percent)
σ_P^2 = Phantom CV (Unknown)
σ_T^2 = Total CV (3.2 percent)

Solving Equation 12 for the phantom CV yields 2.5 percent, which is the empirically determined uncertainty in using different people as clean human phantoms from background measurements on the chest. Most of the people used as clean human phantoms were similar in height, age, weight and gender. However, this specific demographic data was not collected during OT and was not used in analysis of the background data. A similar analysis was performed for background measurements at the throat, resulting in a phantom CV of 1.2 percent, about half the chest value. This can be explained because the throat area is less subject to shielding and source effects.

A group of 169 background measurements of the ratio of "chest to FAC" to "back to FAC" yielded a CV of 3.8 percent indicating a greater variation between chest and back measurements from person to person. This may reflect a greater physical variation in breast muscle/tissue to back muscle/tissue.

A group of 170 background measurements of the ratio of "chest to FAC" to "throat to FAC" yielded a CV of 3.1 percent perhaps for similar reasoning as for the "chest to FAC" to "back to FAC" ratio discussed in the previous paragraph.

Finally, a group of 47 background measurements of the ratio of "back to throat" yielded a CV of 1.5 percent, perhaps reflecting the lower amounts of tissue over the back and throat.

Section 5.

Dose Calculation Methodology

5.1 General Information on Measurements and Dose Calculations

The Canberra ACCUSCAN II and FASTSCAN fixed systems were used in standard U.S. Naval shipyard configurations including calibration set-up, daily checks, and background counts. The E-600/SPA-3 portable system was used in an open window mode (i.e., no photon energy discrimination was done) and therefore all measurements reflected the recording of all detected radiations. As described earlier, it was assumed that placing the SPA-3 probe on the neck yielded a thyroid measurement from I-131. Measurements for cesium were taken using the SPA-3 probe at the chest for males, and on the back for females. Back measurements were used in place of the chest measurements for females to reduce the variability due to varying thicknesses of breast tissue among the women measured.

When operated in scaler mode, the E-600 can be set to display either total counts or average counts per unit time. For background measurements, the E-600 was operated in scaler mode and was set to display the average count rate. Measurements were taken as average cpm over a 10-minute period for thyroid, chest, or back measurements and over a 20-minute period for all background measurements. Measurements from the chest or back were assumed to be from equal activities of Cs-134 (50 percent) and Cs-137 (50 percent).

The E-600/SPA-3 was used in the open window mode with no shielding most of the time that the instrument was used in Japan. Laboratory thyroid measurements showed that this use resulted in 100 percent "cross talk" from cesium deposited in other organs and tissues of the body, primarily in the chest or the back. To address the cross-talk issue for a thyroid count rate it was necessary to subtract the net chest count rate (or the net back count rate) from the net thyroid count rate. This effectively removed the cesium cross talk for the thyroid measurements. The net chest (or back) count rate was used to determine whole body activity with no subtraction of the net thyroid count rate. The cross talk from any I-131 from the thyroid, if present, would add to the chest measurement and make the dose calculation more conservative. Sometimes the thyroid and chest or back were measured one after the other with the same instrument, and sometimes they were measured simultaneously by two different instruments.

All OT RIMIS dose calculations used data from ICRP Publications 68, 71, 78 (ICRP, 1994b; ICRP, 1995; ICRP, 1997) and Potter (2002) as the basis for all calculations and dose conversion values. Details for the calculation of the committed effective dose, $E(\tau)$, and of the committed thyroid equivalent dose, $H_T(\tau)$, are discussed in the next several subsections.

5.2 Activity Ratios of Cs-134 to Cs-137 in Air and Soil

During OT RIMIS operations in March through July of 2011, the assumed ratio of Cs-134 to Cs-137 activity used in the IM dose calculations was 1.0. The validity of this value was confirmed at a later date when several sets of measurements could be collected and analyzed. For example, Cs-134 to Cs-137 activity ratios for U.S. Department of Energy (DOE)

air samples taken at Yokota AB, Yokosuka NB, the U.S. Embassy and in downtown Tokyo during the period March 16–April 18, 2011, are shown in Figure 19. This figure shows that the weighted average of 174 air activity concentration measurements of Cs-134 and Cs-137 was 0.98 ± 0.046. These measurements include 99 measurements that were near the MDA, and 75 measurements with higher activities. The measurements near the MDA had large associated uncertainties, and visually dominate the plot in Figure 19. The measurements with higher activities had much lower uncertainties (less than 10%). Because the weighted average of these measurements was calculated by weighting each measurement using its associated uncertainty (higher uncertainty resulted in lower weighting), the measurements with higher activities and smaller uncertainties dominate the weighted average, resulting in the uncertainty of 4.6 percent.

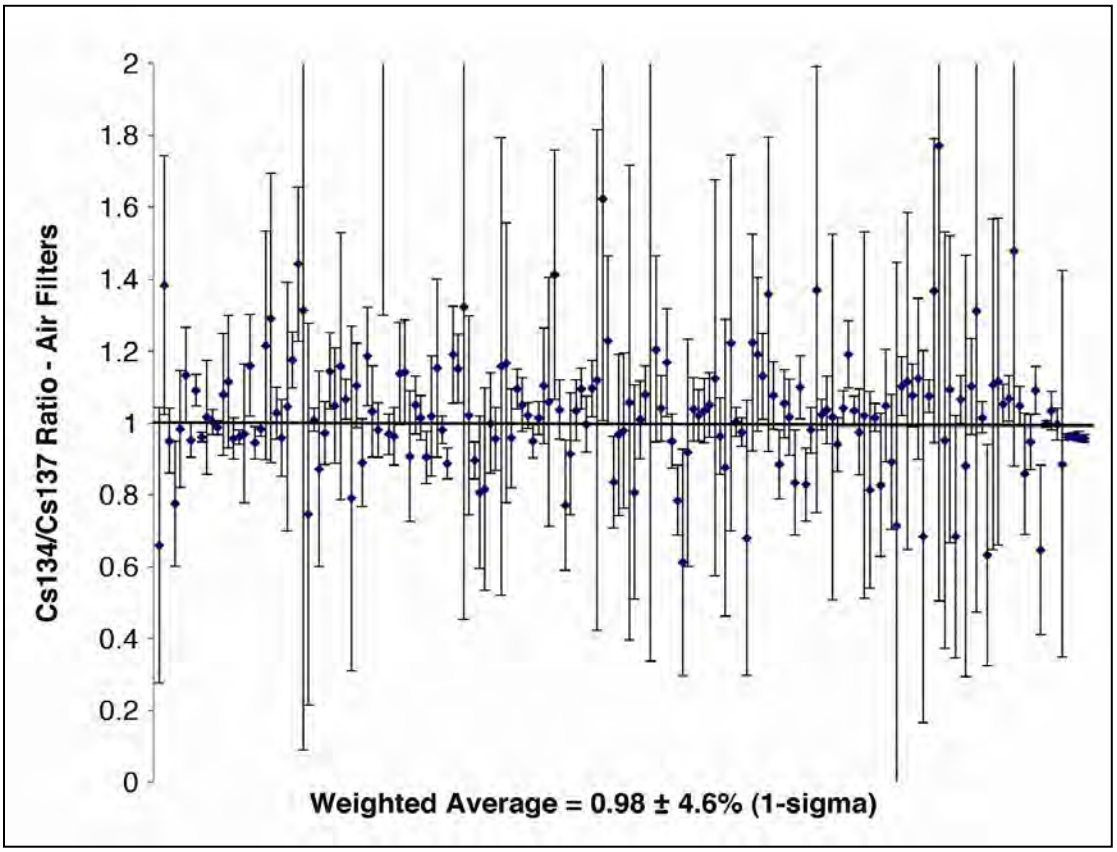


Figure 19. Ratios of Cs-134 to Cs-137 air activity concentration measurements of DOE samples taken at Yokota AB, Yokosuka NB, the U.S. Embassy and in downtown Tokyo
Figure courtesy of Lawrence Livermore National Laboratory

Cs-134 to Cs-137 activity ratios for DOE in-situ measurements in soil around the FDNPS are shown in Figure 20, and show that the weighted average ratio of 179 in-situ soil activity concentration measurements of Cs-134 to Cs-137 was 0.99 ± 0.037 (Musolino et al., 2012). The 1-sigma uncertainty for these measurements is the combined statistical uncertainty of the measurements. The ratios in Figure 19 and Figure 20 reflect ratios of activities at the times of collection. The larger period of collection for the in-situ measurements results in a slight but

visible downward trend in the ratios in Figure 20. This trend results from the shorter radiological half life of Cs-134 as compared to Cs-137.

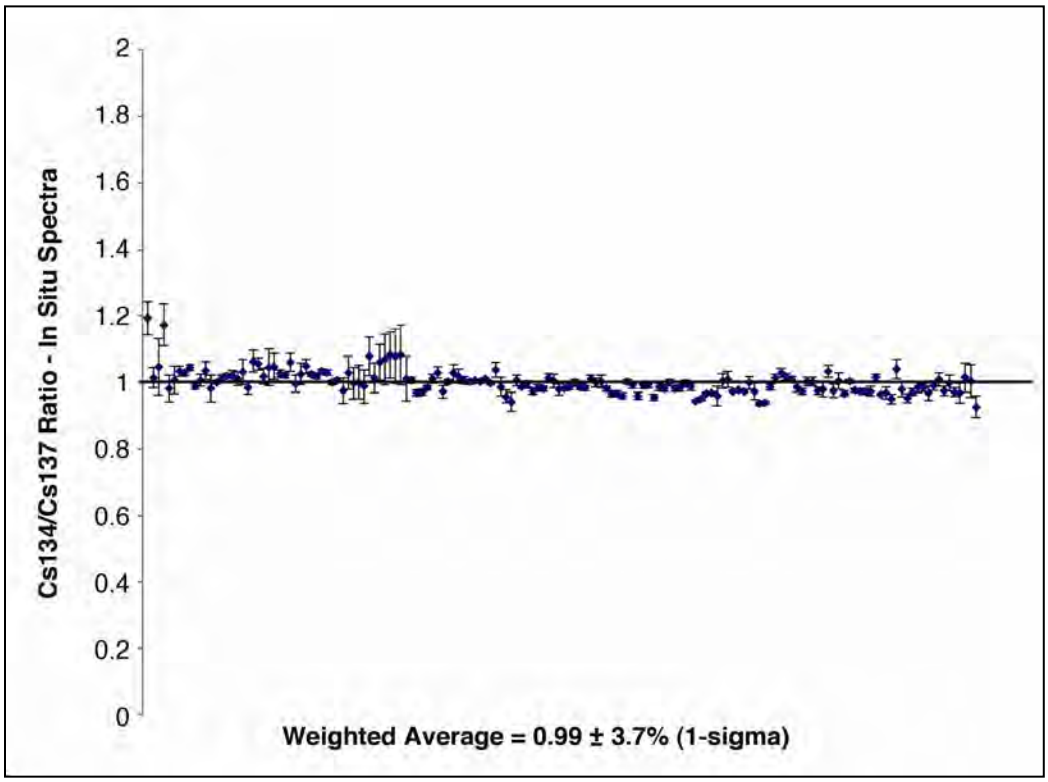


Figure 20. DOE in-situ soil activity concentration measurements around FDNPS
Figure courtesy of Lawrence Livermore National Laboratory

The ratio of Cs-134 to Cs-137 air activity from measurements of the Yokosuka NB 1 m^3 portable air sample that was used to determine all the dose ratios used in the dose equations in this section, and listed in Table 4, was 0.77, which for a single grab sample is reasonably within the variation of measurements in the air concentration data shown in Figure 19.

The average ratios of Cs-134 to Cs-137 air activity concentrations from a series of daily measurements taken during a two-month period from March 12 through May 11, 2011, were 1.01 at Yokota AB and 1.06 at the IMS. The average Cs-134 to Cs-137 air activity ratio from all these measurements rounded to a value of one (1). Additionally, the average Cs-134 to Cs 137 activity ratio from the fixed scanner measurements used to determine the calibration factor for the E-600/SPA-3 measurements was 1.07. Therefore, it was a reasonable assumption to use an activity ratio for Cs-134 to Cs-137 of 1.0. As seen in Table 10, for equal activities of Cs-134 and Cs-137, approximately 72 percent of total cesium photons (Cs-134 and Cs-137) are emitted by Cs-134, and approximately 28 percent are emitted by Cs-137. These "photon fractions" were used for splitting the total counts into contributions from Cs-134 and Cs-137 for E-600/SPA-3 chest and back measurements. This was necessary because the E-600/SPA-3 was operated in an open window mode with no energy discrimination. This method of splitting the E-600/SPA-3 counts based on photon fractions is consistent with the activity determinations made with the software used with the Canberra fixed systems, which takes photon fractions into account with

both ACCUSCAN and FASTSCAN systems. The software uses a library-driven peak search process to identify specific energy peaks and their net areas (counts). Activities for specific isotopes are calculated using the peak areas for specific photon peaks, system-specific energy efficiency data, and library photon yields.

Knowledge of the mode of intake was not needed for interpreting IM measurement results, and intake could be due to inhalation or ingestion. For calculations in this report, it was assumed that the ratio of air activity concentrations also applied to soil activity concentrations.

5.3 Use of Radionuclide Ratios to Calculate Total Doses

Doses were initially calculated for each of three monitored radionuclides (I-131, Cs-134, and Cs-137). In order to account for additional (unmeasured) radionuclides that might also be present, ratios were calculated and used to "scale up" the initially-calculated doses calculated from each single radionuclide to the total dose that would result from all of the nuclides included in the OT RIMIS. These ratios and their uses are discussed in the following subsections.

5.3.1. Committed Effective Dose using ACCUSCAN II and FASTSCAN Measurements

ACCUSCAN II and FASTSCAN thyroid activity measurements from I-131 and whole body activity measurements from Cs-134 and Cs-137 were used to calculate committed effective doses. The calculations were performed using all three measured activities (Equations 13a–13c), including the use of appropriate scaling factors, and the largest of the three calculated effective doses was recorded as the committed effective dose for the person (Equation 14). This was done as a conservative measure so that the largest committed effective dose would be recorded.

$$E(\tau)Acc_{I-131\rightarrow All} = \frac{A_{Thy} \times DC_{I-131}}{IRF_{I-131}} \times \frac{E(\tau)_{All}}{E(\tau)_{I-131}} \quad (13a)$$

$$E(\tau)Acc_{Cs-134\rightarrow All} = \frac{A_{WB} \times DC_{Cs-134}}{IRF_{Cs-134}} \times \frac{E(\tau)_{All}}{E(\tau)_{Cs-134}} \quad (13b)$$

$$E(\tau)Acc_{Cs-137\rightarrow All} = \frac{A_{WB} \times DC_{Cs-137}}{IRF_{Cs-137}} \times \frac{E(\tau)_{All}}{E(\tau)_{Cs-137}} \quad (13c)$$

where:

$E(\tau)Acc_{I\text{-}131\rightarrow All}$ = committed effective dose from all nuclides in the OT RIMIS program based on the ACCUSCAN II or FASTSCAN measurement for I-131 at the thyroid (rem)

$E(\tau)Acc_{Cs\text{-}134\rightarrow All}$ = committed effective dose from all nuclides in the OT RIMIS program based on the ACCUSCAN II or FASTSCAN measurement for Cs-134 at the chest or back (rem)

$E(\tau)Acc_{Cs\text{-}137\rightarrow All}$ = committed effective dose from all nuclides in the OT RIMIS program based on the ACCUSCAN II or FASTSCAN measurement for Cs-137 at the chest or back (rem)

A_{Thy} = ACCUSCAN II or FASTSCAN thyroid activity measurement (nCi [Bq])

A_{WB} = ACCUSCAN II or FASTSCAN whole body activity measurement (nCi [Bq])

$$E(\tau)Acc = Max\ of\ \{E(\tau)Acc_{I-131\rightarrow All}, E(\tau)Acc_{Cs-134\rightarrow All}, E(\tau)Acc_{Cs-137\rightarrow All}\} \quad (14)$$

where $E(\tau)Acc$ is the committed effective dose based on ACCUSCAN II or FASTSCAN measurements in rem.

5.3.2. Committed Equivalent Dose to the Thyroid using ACCUSCAN II and FASTSCAN Measurements

ACCUSCAN II and FASTSCAN thyroid activity measurements from I-131 and whole body activity measurements from Cs-134 and Cs-137 were used to calculate committed equivalent doses to the thyroid. The calculations were performed using all three measured activities (Equations 15a–15c), including the use of appropriate scaling factors, and the largest of the three calculated equivalent doses was recorded as the committed equivalent dose to the thyroid for the person (Equation 16). This was done as a conservative measure so that the largest committed equivalent dose to the thyroid would be recorded.

$$H_T(\tau)Acc_{I-131\rightarrow All} = \frac{A \times DC_{Thy,\ I-131}}{IRF_{I-131}} \times \frac{H_T(\tau)_{All}}{H_T(\tau)_{I-131}} \quad (15a)$$

$$H_T(\tau)Acc_{Cs-134\rightarrow All} = E(\tau)_{Cs-134\rightarrow All} \times \frac{H_T(\tau)_{All}}{E(\tau)_{All}} \quad (15b)$$

$$H_T(\tau)Acc_{Cs-137\rightarrow All} = E(\tau)_{Cs-137\rightarrow All} \times \frac{H_T(\tau)_{All}}{E(\tau)_{All}} \quad (15c)$$

$$H_T(\tau)Acc = Max\ of\ \{H_T(\tau)Acc_{I-131\rightarrow All}, H_T(\tau)Acc_{Cs-134\rightarrow All}, H_T(\tau)Acc_{Cs-137\rightarrow All}\} \quad (16)$$

where:

$H_T(\tau)Acc_{I\text{-}131\rightarrow All}$ = committed equivalent dose to the thyroid from all radionuclides in the OT RIMIS program based on the ACCUSCAN II or FASTSCAN measurement for I-131 at the thyroid (rem)

$H_T(\tau)Acc_{Cs\text{-}134\rightarrow All}$ = committed equivalent dose to the thyroid from all radionuclides in the OT RIMIS program based on the ACCUSCAN II or FASTSCAN measurement for Cs-134 at the chest or back (rem)

$H_T(\tau)Acc_{Cs\text{-}137\rightarrow All}$ = committed equivalent dose from all radionuclides in the OT RIMIS program based on the ACCUSCAN II or FASTSCAN measurement for Cs-137 at the chest or back (rem)

$H_T(\tau)Acc$ = committed equivalent dose to the thyroid based on ACCUSCAN II or FASTSCAN measurements (rem)

5.3.3. Committed Effective Dose using E-600/SPA-3 Measurements

Measurements from the thyroid and chest (male) or thyroid and back (female) were used to calculate committed effective dose. The committed effective doses for three radionuclides were first calculated: I-131 measurements (thyroid), Cs-134 and Cs-137 measurements (chest or back). Each of these calculated doses was then multiplied by a unique scaling ratio of committed effective doses. The scaling ratios are the ratio of committed effective dose calculated using the measured air activity concentrations of six radionuclides at Yokosuka NB (see Table 4) to the effective dose calculated using a single radionuclide. The scaling ratios were used to scale up the committed effective dose calculated from a single nuclide to the total committed effective dose that would result from all six of the nuclides included in the OT RIMIS dose calculations (as shown in e.g., Table 19). The equations used to calculate committed effective dose from the three radionuclides are shown in Equations 17a–17c.

$$E(\tau)_{I-131\rightarrow All} = \frac{\left[(G-Bkg)_{Thy}-C\right] \times CF_{I-131} \times DC_{I-131}}{IRF_{I-131}} \times \frac{E(\tau)_{All}}{E(\tau)_{I-131}} \quad (17a)$$

$$E(\tau)_{Cs-134\rightarrow All} = \frac{Net_{E600} \times \overline{CF}_{Cs-134\,E600} \times DC_{Cs-134}}{IRF_{Cs-134}} \times \frac{E(\tau)_{All}}{E(\tau)_{Cs-134}} \quad (17b)$$

$$E(\tau)_{Cs-137\rightarrow All} = \frac{Net_{E600} \times \overline{CF}_{Cs-137\,E600} \times DC_{Cs-137}}{IRF_{Cs-137}} \times \frac{E(\tau)_{All}}{E(\tau)_{Cs-137}} \quad (17c)$$

where:

$E(\tau)_{I\text{-}131\rightarrow All}$ = the committed effective dose from all nuclides in the OT RIMIS program based on the measured I-131 at the thyroid (rem)

$E(\tau)_{Cs\text{-}134\rightarrow All}$ = the committed effective dose from all nuclides in the OT RIMIS program based on the measured Cs-134 at the chest or back (rem)

$E(\tau)_{Cs\text{-}137\rightarrow All}$ = the committed effective dose from all nuclides in the OT RIMIS program based on the measured Cs-137 at the chest or back (rem)

G = the average gross count rate during a 10-minute period, taken on the throat at the thyroid (for I-131) (cpm)

Bkg = the average background count rate during a 20-minute period taken at the throat over the thyroid (for I-131) (cpm)

C = equal to [*G-Bkg*] at the chest or back, which is the average gross count rate (*G*) taken on the chest or back of the person being measured minus the average background count rate (*B*) taken on the chest or back of the person used as a certified clean human phantom (cpm)

$CF_{\text{I-131}}$ = the detector calibration factor for I-131; determined empirically using a thyroid phantom with an I-131 sample traceable to a national standard (0.0053 nCi cpm^{-1} [0.20 Bq cpm^{-1}])

DC = age-dependent effective dose coefficient for Cs-134, Cs-137, or I-131 (rem nCi^{-1} [Sv Bq^{-1}])

IRF = Intake Retention Fraction for inhalation at the elapsed time between intake and measurement for Cs-134, Cs-137, or I-131 (unitless)

$\frac{E(\tau)_{All}}{E(\tau)_{X-xxx}}$ = scaling ratios of committed effective dose from all radionuclides in the OT RIMIS program to committed effective dose from a single radionuclide X-xxx, designated as follows in subsequent figures: Ratio 1 = $\frac{E(\tau)_{All}}{E(\tau)_{I-131}}$; Ratio 3 = $\frac{E(\tau)_{All}}{E(\tau)_{Cs-134}}$; and Ratio 4 = $\frac{E(\tau)_{All}}{E(\tau)_{Cs-137}}$ (unitless)

The age-dependent DCs were taken from the ICRP databases of DCs (ICRP, 2003; ICRP, 2007b). IRF values for adults were taken from Potter (2002) and are based on ICRP Publication 68 (ICRP, 1994b). Age-dependent IRF values were calculated as shown previously in this report. Note that age-dependent factors were used only for Cs-134 and Cs-137 (i.e., not for I-131). Adult values were used for I-131 to simplify the calculations and because the differences were small (a factor of three difference during the first 30 days following exposure). Additionally, the adult values result in doses that have additional conservatism when used for a child.

Values for the scaling ratios (1, 3, and 4) of committed effective doses that are used to account for air activity concentration of all the OT RIMIS nuclides can be found in Table 19–Table 24. The air activity concentration data used in these tables are the measured activities in the air sample collected near Yokosuka NB as described earlier. These air concentrations are entered in the yellow-shaded cells in the column labeled "Activity (pCi m^{-3})" in Table 19–Table 24. Note that the Cs-134 to Cs-137 ratio for these measurements was 0.77. Also, use of the Cs-134 and Cs-137 activity concentrations shown in Table 19–Table 24 to calculate the ratio used with the measured Cs-134 dose (Equation 17b), turns out to be conservative because it makes the ratio of doses (used as a multiplier) larger than if equal activity concentrations were assumed. It should be noted that the assumption that the activity concentrations of Cs-134 and Cs-137 are equal when used in determination of calibration factors for E-600/SPA-3 portable instruments is still valid since each of these figures depicts a single measurement.

Table 19. Activities, dose coefficients, doses, and dose ratios for ages greater than 17 years

Radio-nuclide	Activity (pCi m^{-3})	Activity Ratio Relative to I-131	Thyroid Equivalent DC (Sv Bq^{-1})	Thyroid Equivalent DC (mrem nCi^{-1})	Effective DC (Sv Bq^{-1})	Effective DC (mrem nCi^{-1})	Equivalent Dose Thyroid (mrem)	Effective Dose (mrem)	Ratio Equivalent to Effective
I-131	3.9E+03*	1.0E+00	1.5E-07	5.6E-01	7.4E-09	2.7E-02	2,200	110	20
I-133	5.6E+02	1.4E-01	2.8E-08	1.0E-01	1.5E-09	5.6E-03	58	310	19
Te-132	3.5E+03	8.9E-01	2.5E-08	9.3E-02	1.8E-09	6.7E-03	320	23	14
I-132	2.1E+03	5.4E-01	1.4E-09	5.2E-03	9.4E-11	3.5E-04	11	0.74	15
Cs-134	4.3E+02	1.1E-01	6.3E-09	2.3E-02	6.6E-09	2.4E-02	10	10	0.95
Cs-137	5.6E+02	1.4E-01	4.4E-09	1.6E-02	4.6E-09	1.7E-02	9.1	9.5	0.96
	Total						2,600	150	
	E(τ) Cs-134 / E(τ) Cs-137							1.1	
	Ratio 1 = E(τ)(I-131,132,133, Cs-134,137, Te-132) / E(τ)(I-131)							1.4	
	Ratio 2 = H_T(τ)(I-131,132,133, Cs-134,137, Te-132) / H_T(τ)(I-131)						1.2		
	Ratio 3 = E(τ)(I-131,132,133, Cs-134, 137, Te-132) / E(τ)(Cs-134)							15	
	Ratio 4 = E(τ(I-131,132,133, Cs-134, 137, Te-132) / E(τ)(Cs-137)							16	
	Ratio 5 = Total H_T(τ) / Total E(τ)								17

* Scientific E notation is used here and elsewhere in this report, where "E" signifies "times 10 raised to the power of." For example, 3.9E+3 signifies 3.9×10^3.

Table 20. Activities, dose coefficients, doses, and dose ratios for ages greater than 12 and less than or equal to 17 years

Radio-nuclide	Activity (pCi m^{-3})	Activity Ratio Relative to I-131	Thyroid Equivalent DC (Sv Bq^{-1})	Thyroid Equivalent DC (mrem nCi^{-1})	Effective DC (Sv Bq^{-1})	Effective DC (mrem nCi^{-1})	Equivalent Dose Thyroid (mrem)	Effective Dose (mrem)	Ratio Equivalent to Effective
I-131	3.9E+03*	1.0E+00	2.2E-07	8.1E-01	1.1E-08	4.1E-02	3,200	160	20
I-133	2.1E+03	5.4E-01	2.1E-09	7.8E-03	1.3E-10	4.8E-04	17	1.0	16
Te-132	5.6E+02	1.4E-01	4.4E-08	1.6E-01	2.2E-09	8.1E-03	92	4.6	20
I-132	3.5E+03	8.9E-01	3.8E-08	1.4E-01	2.6E-09	9.6E-03	490	34	15
Cs-134	4.3E+02	1.1E-01	6.1E-09	2.3E-02	6.3E-09	2.3E-02	9.7	10	0.97
Cs-137	5.6E+02	1.4E-01	4.2E-09	1.6E-02	4.4E-09	1.6E-02	8.6	9.1	0.95
	Total						3,800	220	
	E(τ) Cs-134 / E(τ) Cs-137							1.1	
	Ratio 1 = E(τ)(I-131,132,133, Cs-134,137, Te-132) / E(τ)(I-131)							1.4	
	Ratio 2 = H_T(τ)(I-131,132,133, Cs-134,137, Te-132) / H_T(τ)(I-131)						1.2		
	Ratio 3 = E(τ)(I-131,132,133, Cs-134, 137, Te-132) / E(τ)(Cs-134)							22	
	Ratio 4 = E(τ)(I-131,132,133, Cs-134, 137, Te-132) / E(τ)(Cs-137)							24	
	Ratio 5 = Total H_T(τ) / Total E(τ)								17

* Scientific E notation is used here and elsewhere in this report, where "E" signifies "times 10 raised to the power of." For example, 3.9E+3 signifies 3.9×10^3.

Table 21. Activities, dose coefficients, doses and dose ratios for ages greater than 7 and less than or equal to 12 years

Radio-nuclide	Activity (pCi m^{-3})	Activity Ratio Relative to I-131	Thyroid Equivalent DC (Sv Bq^{-1})	Thyroid Equivalent DC (mrem nCi^{-1})	Effective DC (Sv Bq^{-1})	Effective DC (mrem nCi^{-1})	Equivalent Dose Thyroid (mrem)	Effective Dose (mrem)	Ratio Equivalent to Effective
I-131	3.9E+03*	1.0E+00	3.7E-07	1.4E+00	1.9E-08	7.0E-02	5,400	280	19
I-133	2.1E+03	5.4E-01	3.4E-09	1.3E-02	2.2E-10	8.1E-04	27	1.7	15
Te-132	5.6E+02	1.4E-01	7.4E-08	2.7E-01	3.8E-09	1.4E-02	150	7.9	19
I-132	3.5E+03	8.9E-01	6.1E-08	2.3E-01	4.2E-09	1.6E-02	790	54	15
Cs-134	4.3E+02	1.1E-01	5.1E-09	1.9E-02	5.3E-09	2.0E-02	8.1	8.4	0.96
Cs-137	5.6E+02	1.4E-01	3.5E-09	1.3E-02	3.7E-09	1.4E-02	7.2	7.6	0.95
	Total						6,400	360	
	$E(\tau)$ Cs-134 / $E(\tau)$ Cs-137							1.1	
	Ratio 1 = $E(\tau)$(I-131,132,133, Cs-134,137, Te-132) / $E(\tau)$(I-131)							1.3	
	Ratio 2 = $H_T(\tau)$(I-131,132,133, Cs-134,137, Te-132) / $H_T(\tau)$(I-131)						1.2		
	Ratio 3 = $E(\tau)$(I-131,132,133, Cs-134, 137, Te-132) / $E(\tau)$(Cs-134)							43	
	Ratio 4 = $E(\tau)$(I-131,132,133, Cs-134, 137, Te-132) / $E(\tau)$(Cs-137)							47	
	Ratio 5 = Total $H_T(\tau)$ / Total $E(\tau)$								18

* Scientific E notation is used here and elsewhere in this report, where "E" signifies "times 10 raised to the power of." For example, 3.9E+3 signifies 3.9×10^3.

Table 22. Activities, dose coefficients, doses and dose ratios for ages greater than 2 and less than or equal to 7 years

Radio-nuclide	Activity (pCi m^{-3})	Activity Ratio Relative to I-131	Thyroid Equivalent DC (Sv Bq^{-1})	Thyroid Equivalent DC (mrem nCi^{-1})	Effective DC (Sv Bq^{-1})	Effective DC (mrem nCi^{-1})	Equivalent Dose Thyroid (mrem)	Effective Dose (mrem)	Ratio Equivalent to Effective
I-131	3.9E+03*	1.0E+00	7.3E-07	2.7E+00	3.7E-08	1.4E-01	11,000	540	20
I-133	2.1E+03	5.4E-01	7.6E-09	2.8E-02	4.5E-10	1.7E-03	60	3.5	17
Te-132	5.6E+02	1.4E-01	1.6E-07	5.9E-01	8.3E-09	3.1E-02	330	17	19
I-132	3.5E+03	8.9E-01	1.4E-07	5.2E-01	8.5E-09	3.1E-02	1,800	110	16
Cs-134	4.3E+02	1.1E-01	4.7E-09	1.7E-02	5.2E-09	1.9E-02	7.4	8.2	0.9
Cs-137	5.6E+02	1.4E-01	3.2E-09	1.2E-02	3.6E-09	1.3E-02	6.6	7.4	0.89
	Total						13,000	690	
	$E(\tau)$ Cs-134 / $E(\tau)$ Cs-137							1.1	
	Ratio 1 = $E(\tau)$(I-131,132,133, Cs-134,137, Te-132) / $E(\tau)$(I-131)							1.3	
	Ratio 2 = $H_T(\tau)$(I-131,132,133, Cs-134,137, Te-132) / $H_T(\tau)$(I-131)						1.2		
	Ratio 3 = $E(\tau)$(I-131,132,133, Cs-134, 137, Te-132) / $E(\tau)$(Cs-134)							83	
	Ratio 4 = $E(\tau)$(I-131,132,133, Cs-134, 137, Te-132) / $E(\tau)$(Cs-137)							93	
	Ratio 5 = Total $H_T(\tau)$ / Total $E(\tau)$								19

* Scientific E notation is used here and elsewhere in this report, where "E" signifies "times 10 raised to the power of." For example, 3.9E+3 signifies 3.9×10^3.

Table 23. Activities, dose coefficients, doses and dose ratios for ages greater than 1 and less than or equal to 2 years

Radio-nuclide	Activity (pCi m^{-3})	Activity Ratio Relative to I-131	Thyroid Equivalent DC (Sv Bq^{-1})	Thyroid Equivalent DC (mrem nCi^{-1})	Effective DC (Sv Bq^{-1})	Effective DC (mrem nCi^{-1})	Equivalent Dose Thyroid (mrem)	Effective Dose (mrem)	Ratio Equivalent to Effective
I-131	3.9E+03*	1.0E+00	1.4E-06	5.2E+00	7.2E-08	2.7E-01	20,000	1,000	19
I-133	2.1E+03	5.4E-01	1.6E-08	5.9E-02	9.6E-10	3.6E-03	130	7.5	17
Te-132	5.6E+02	1.4E-01	3.5E-07	1.3E+00	1.8E-08	6.7E-02	730	37	19
I-132	3.5E+03	8.9E-01	2.9E-07	1.1E+00	1.8E-08	6.7E-02	3,800	230	16
Cs-134	4.3E+02	1.1E-01	6.3E-09	2.3E-02	7.3E-09	2.7E-02	10	12	0.86
Cs-137	5.6E+02	1.4E-01	4.4E-09	1.6E-02	5.4E-09	2.0E-02	9.1	11	0.81
	Total						25,000	1,400	
	E(τ) Cs-134 / E(τ) Cs-137							1.0	
	Ratio 1 = E(τ)(I-131,132,133, Cs-134,137, Te-132) / E(τ)(I-131)							1.3	
	Ratio 2 = $H_T(\tau)$(I-131,132,133, Cs-134,137, Te-132) / $H_T(\tau)$(I-131)						1.2		
	Ratio 3 = E(τ)(I-131,132,133, Cs-134, 137, Te-132) / E(τ)(Cs-134)							120	
	Ratio 4 = E(τ)(I-131,132,133, Cs-134, 137, Te-132) / E(τ)(Cs-137)							120	
	Ratio 5 = Total $H_T(\tau)$ / Total E(τ)								19

* Scientific E notation is used here and elsewhere in this report, where "E" signifies "times 10 raised to the power of." For example, 3.9E+3 signifies 3.9×10^3.

Table 24. Activities, dose coefficients, doses and dose ratios for ages less than or equal to 1 year

Radio-nuclide	Activity (pCi m^{-3})	Activity Ratio Relative to I-131	Thyroid Equivalent DC (Sv Bq^{-1})	Thyroid Equivalent DC (mrem nCi^{-1})	Effective DC (Sv Bq^{-1})	Effective DC (mrem nCi^{-1})	Equivalent Dose Thyroid (mrem)	Effective Dose (mrem)	Ratio Equivalent to Effective
I-131	3.9E+03*	1.0E+00	1.4E-06	5.2E+00	7.2E-08	2.7E-01	20,000	1,000	19
I-133	2.1E+03	5.4E-01	1.8E-08	6.7E-02	1.1E-09	4.1E-03	140	8.6	16
Te-132	5.6E+02	1.4E-01	3.8E-07	1.4E+00	1.9E-08	7.0E-02	790	40	20
I-132	3.5E+03	8.9E-01	3.6E-07	1.3E+00	2.2E-08	8.1E-02	4,700	280	16
Cs-134	4.3E+02	1.1E-01	1.0E-08	3.7E-02	1.1E-08	4.1E-02	16	17	0.91
Cs-137	5.6E+02	1.4E-01	7.5E-09	2.8E-02	8.8E-09	3.3E-02	15	18	0.85
	Total						26,000	1,400	
	E(τ) Cs-134 / E(τ) Cs-137							0.96	
	Ratio 1 = E(τ)(I-131,132,133, Cs-134,137, Te-132) / E(τ)(I-131)							1.4	
	Ratio 2 = $H_T(\tau)$(I-131,132,133, Cs-134,137, Te-132) / $H_T(\tau)$(I-131)						1.3		
	Ratio 3 = E(τ)(I-131,132,133, Cs-134, 137, Te-132) / E(τ)(Cs-134)							81	
	Ratio 4 = E(τ)(I-131,132,133, Cs-134, 137, Te-132) / E(τ)(Cs-137)							78	
	Ratio 5 = Total $H_T(\tau)$ / Total E(τ)								18

* Scientific E notation is used here and elsewhere in this report, where "E" signifies "times 10 raised to the power of." For example, 3.9E+3 signifies 3.9×10^3.

The three values calculated using Equations 17a–17c were compared and the maximum value was used to calculate the committed effective dose for the individual being measured, as shown in Equation 18. This was done as a conservative measure so that the largest committed effective dose would be recorded.

$$E(\tau) = Max\ of\ \{E(\tau)_{I-131\rightarrow All}, E(\tau)_{Cs-134\rightarrow All}, E(\tau)_{Cs-137\rightarrow All}\}, \quad (18)$$

where $E(\tau)$ is the committed effective dose in rem.

5.3.4. Committed Equivalent Dose to the Thyroid using E-600/SPA-3 Measurements

Measurements from the thyroid and chest (male) or thyroid and back (female) were used to calculate committed equivalent dose to the thyroid. The calculations were done for I-131 measurements (thyroid), Cs-134, and Cs-137 measurements (chest or back). Each of these calculated doses was then multiplied by a unique scaling ratio of committed equivalent doses. The scaling ratio used for I-131 would effectively scale up the committed equivalent dose from I-131 to include all radionuclides in the OT RIMIS program, and the scaling ratio used for Cs-134 and Cs-137 would convert the committed effective dose from each cesium isotope to the committed equivalent dose to the thyroid from all radionuclides included in the RIMIS program. The equations used to calculate committed equivalent dose to the thyroid from each of the three radionuclides are shown in Equations 19a–19c.

The scaling ratio used in Equation 19a scales up the committed equivalent dose from I-131 to an equivalent dose from all the nuclides in the OT RIMIS program (see Table 4), and the scaling ratio used in Equations 19b and 19c converts the committed effective dose from a single cesium isotope to the committed equivalent dose to the thyroid from all nuclides.

$$H_T(\tau)_{I-131\rightarrow All} = \frac{\left[G_{Thy} - Bkg_{Thy} - C\right] \times CF_{I-131} \times DC_{Thy,\ I-131}}{IRF_{I-131}} \times \frac{H_T(\tau)_{All}}{H_T(\tau)_{I-131}} \quad (19a)$$

$$H_T(\tau)_{Cs-134\rightarrow All} = E(\tau)_{Cs-134\rightarrow All} \times \frac{H_T(\tau)_{All}}{E(\tau)_{All}} \quad (19b)$$

$$H_T(\tau)_{Cs-137\rightarrow All} = E(\tau)_{Cs-137\rightarrow All} \times \frac{H_T(\tau)_{All}}{E(\tau)_{All}} \quad (19c)$$

where:

$H_T(\tau)_{I-131\rightarrow All}$ = committed equivalent dose to the thyroid from all nuclides in the OT RIMIS program based on the measured I-131 on the thyroid (rem)

$H_T(\tau)_{Cs-134\rightarrow All}$ = committed equivalent dose to the thyroid from all nuclides in the OT RIMIS program based on the measured Cs-134 at the chest or back (rem)

$H_T(\tau)_{Cs\text{-}137\rightarrow All}$ = committed equivalent dose to the thyroid from all nuclides in the OT RIMIS program based on the measured Cs-137 at the chest or back (rem)

G_{Thy} = average gross count rate over a 10-minute period, taken on the throat over the thyroid (cpm)

Bkg_{Thy} = average background count rate over a 20-minute period taken on the throat over the thyroid (cpm)

$DC_{Thy,\ I\text{-}131}$ = age-dependent thyroid equivalent dose coefficients for I-131 from ICRP databases of DCs (ICRP, 2003 and 2007b) (rem nCi^{-1} [Sv Bq^{-1}])

$IRF_{I\text{-}131}$ = Intake Retention Fraction for inhalation for the elapsed time between intake and measurement for I-131 (unitless)

$\frac{H_T(\tau)_{All}}{H_T(\tau)_{I-131}}$ = ratio of committed equivalent doses from all radionuclides in the OT RIMIS program to that from I-131 (designated as "Ratio 2") (unitless)

$\frac{H_T(\tau)_{All}}{E(\tau)_{All}}$ = ratio of the committed equivalent dose to the thyroid from all radionuclides to the committed effective dose from all radionuclides, used to convert calculated committed effective dose from a single cesium isotope (Cs-134 or Cs-137) to the committed equivalent dose to the thyroid from all radionuclides in the OT RIMIS program, designated as "Ratio 5" (unitless)

Intake retention fractions for adults were taken from Potter (2002) and are based on ICRP Publication 68 (ICRP, 1994b). Age-dependent factors were calculated as shown in Section 3.3 of this report. However, note that age-dependent factors were used only for Cs-134 and Cs-137 and not I-131. The adult values were used for I-131 to simplify the calculations and because the differences were small (a factor of three difference during the first 30 days and later it was shown that there were no iodine activity concentration measurements above MDA). Values of the scaling ratios (2 and 5) can be found in Table 19–Table 24. The air activity concentration data used in these tables are from measured values of radioactivity on air samples taken near Yokosuka NB as described previously.

Each of the three values calculated by Equations 19a–19c were compared and the maximum value was the one used to reflect the committed equivalent dose to the thyroid for the person as shown in Equation 20. This was done as a conservative measure so that the largest committed equivalent dose to the thyroid would be recorded.

$$H_T(\tau) = Max\ of\ \{H_T(\tau)_{I-131\rightarrow All}, H_T(\tau)_{Cs-134\rightarrow All}, H_T(\tau)_{Cs-137\rightarrow All}\}, \qquad (20)$$

where $H_T(\tau)$ is the committed equivalent dose to the thyroid in rem.

Section 6.

Internal Activity and Dose Calculation Tool

To standardize the calculation of OT RIMIS doses using the equations described in Section 5, an automated spreadsheet-based tool was developed. The tool is called the Internal Activity and Dose Calculation Tool (IADCT), and was written in a Microsoft Excel® workbook. Tool input consisted of a few measurements and individual personal demographic data entry. There have been 13 IADCT versions, each with a new sequential version number, since the initial release on April 11, 2011.

All IADCT versions were designed for personnel performing the OT RIMIS fixed and portable instrument system measurements. The IADCT workbook was supplied to field stations in a protected format, with only selected input cells available for use by field personnel. The preferred practice in the field was that the person would be internally monitored with the portable instrument system and then the fixed system during the same visit whenever possible. This supported correlation between fixed and portable instrument systems and facilitated calibration of the portable instruments.

The IADCT tool automatically generated a report that listed the person's demographic data, the measurement data, and the dose results for both the fixed and portable IM measurements on a single row. Whenever a new version of IADCT was implemented, all previously collected raw input count and activity data were reprocessed using the revised algorithm to obtain results based on the latest version. A separate file of raw input count and activity data was maintained and used as the starting point for input to the IADCT. Processing the raw input data in the IADCT was automated using macros.

Although numerical IADCT dose results were calculated by OT RIMIS personnel in the field during IM operations, the operator did not provide monitored individuals a numerical dose result. This was a program management decision, since providing dose numbers might confuse monitored individuals without appropriate interpretation. Instead, monitored individuals were given a qualitative characterization of their calculated dose during a post-scan briefing. The qualitative characterization was provided in one of three ways depending on the magnitude of their calculated dose.

For monitoring results less than the MDA the person was told:

> "Monitoring results showed that even with the most sensitive equipment, no measureable radioactive material was detected above natural levels. No further evaluation is necessary."

For monitoring results greater than MDA but producing committed effective doses less than or equal to 0.5 rem (5 mSv) the person was told:

> "Monitoring results showed that a very small amount of radioactive material was detected. Intake of this amount of radioactivity would produce a whole body dose lower than that received from living in Denver, Colorado for a year. This amount has no medical significance and adverse health effects are not expected. This material will break down naturally in the body, is not a health concern and poses no threat to

members of your household. There is no need to change any of your daily activities and there is no medical evaluation or treatment that is necessary."

For monitoring results producing committed effective doses in excess of 0.5 rem (5 mSv) the person would have been told (there were none of these cases):

"Monitoring results indicated radioactive material was detected during the testing. The level of radioactivity detected is not expected to cause adverse health effects. As a precaution, we are referring you to the Occupational Health Clinic at the hospital. The Occupational Medicine physician will examine you and determine if further testing and/or regular follow-up is required. This is not a medical emergency and you are not in any danger. The Occupational Medicine physician will also be able to answer other questions you may have. The material found will break down naturally in the body, is not a health concern and poses no threat to members of your household. There is no need to change any of your daily activities."

Examples of the operator's input worksheet containing hypothetical input information are shown in Figure 21–Figure 23 to illustrate the progress of algorithm development through the series of revisions. Figure 21 illustrates the original version (1.0), which had a relatively simple screen input. This first version did not contain a place to enter different background measurements for the throat (thyroid) and chest (male) or back (females). As the calculations were refined and made more conservative, the input screen evolved and became more complicated as shown by Figure 22 and Figure 23. In all versions of IADCT the yellow highlighted blocks are operator input fields; a push button in the operator's input tab sheet launched the macro that processed the input information and placed it on a single row in the spreadsheet. [Note that in some of the earlier versions of IADCT, terminology, abbreviations, and acronyms used in the spreadsheet were different from those used in the text of this report.] This occurred for the two reasons discussed in the following paragraphs.

First, it was desirable to use an a simple acronym that reflected the words rather than use symbols, such as Committed Dose Equivalent (CDE) and committed effective dose equivalent (CEDE). Also, these acronyms have been used historically by many Federal agencies. The current version of 10 CFR 20 (and ICRP 30, 1979) defines the committed dose equivalent ($H_{T,50}$) as the dose equivalent to organs or tissues of reference (T) that will be received from an intake of radioactive material by an individual during the 50-year period following the intake, and, the committed effective dose equivalent ($H_{E,50}$) is the sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues ($H_{E,50} = \Sigma W_T H_{T,50}$)

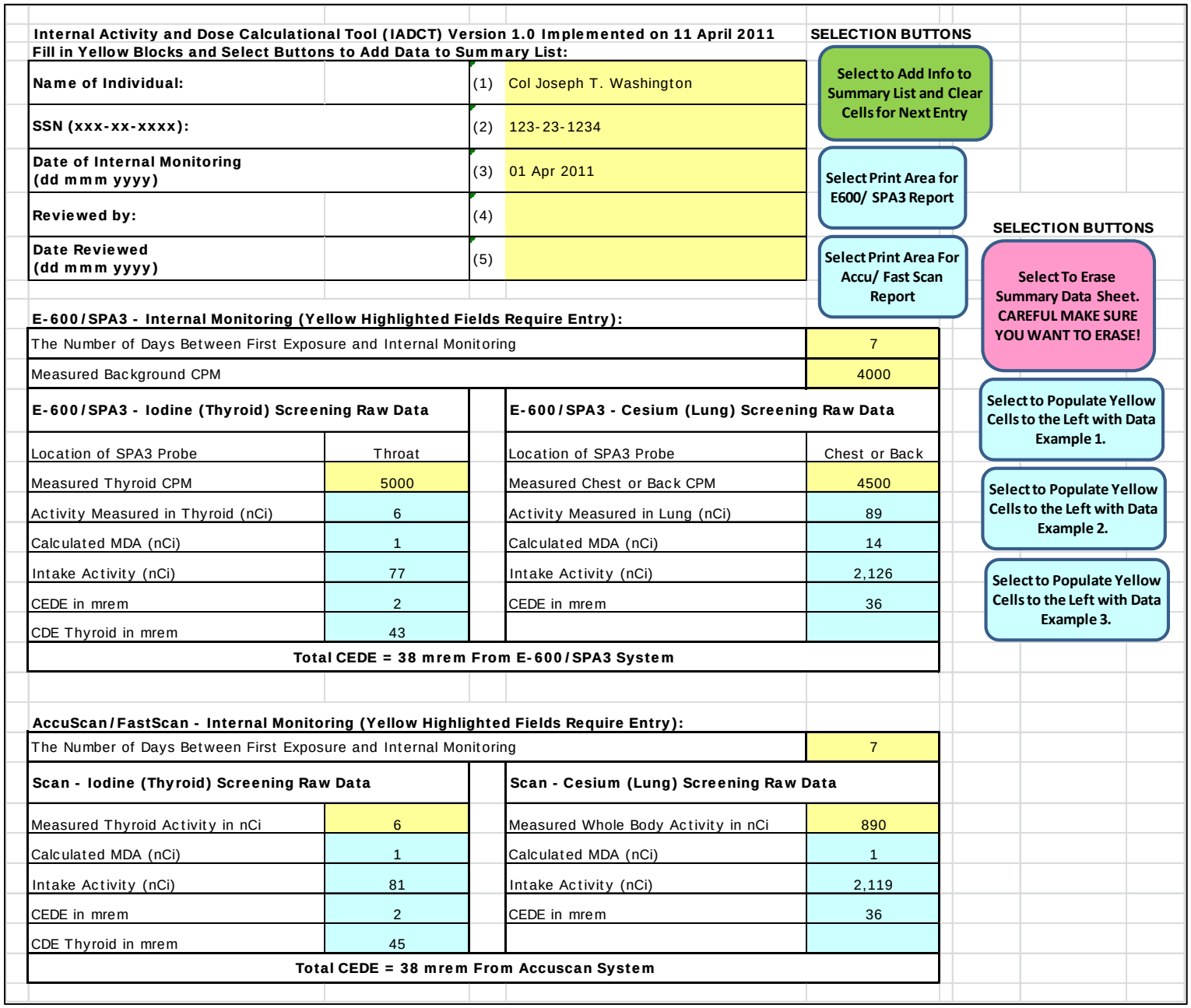
Second, it was decided to use the concepts of ICRP 60 (1990) and later, which redefined the quantities and provided new names and symbols, and that were based on the newest data and newest definitions of tissue weighting factors. The **committed effective dose equivalent** (CEDE or $H_{E,50}$) of ICRP 30 became the **committed effective dose** [$E(\tau)$] of ICRP 60, and is defined as the effective dose to the body from internally deposited radionuclides during the period τ following an intake. For workers a period of 50 years is used; for members of the public the period is 50 years and for children the period is from exposure to age 70). The **committed dose equivalent** (CDE or $H_{T,50}$) of ICRP 30 became the **committed equivalent dose** [$H_{T,\tau}$ or $H_T(\tau)$] of ICRP 60, and is defined as the equivalent dose to a tissue or organ from internally deposited radionuclides during the period τ following an intake. For workers a period of 50 years

is used; for members of the public the period is 50 years and for children the period is from exposure to age 70.

A maximum of 500 entries was allowed in each IADCT file, which was a sufficient number because a new workbook was opened each day. Both shifts of a single day were put into one workbook file. Each workbook was given a file name that started with the date of the measurements, followed by the IM location, the last name of the IM SM, and a short abbreviation or acronym indicating the population monitored. Each electronic workbook was password-protected using a common password provided to all operators.

The completed paper copies of the E-600/SPA-3 Personnel Monitoring Data Sheets, E-600/SPA-3 background data sheet, and ACCUSCAN and FASTSCAN printouts were electronically scanned into a series of portable document format (PDF) files daily or as operational conditions permitted with similar file names to those used for the spreadsheets. Each day all IM SMs accessed the DOEHS to upload the spreadsheet and PDF files to DOEHS, which served as the data repository. Additionally, each week a new Compact Disc (CD) was created and mailed to the NDC along with all the paperwork. The NDC was tasked to acknowledge submission receipt.

Additional details about IM procedures may be found in the appendices.



Internal Activity and Dose Calculational Tool (IADCT) Version 1.0 Implemented on 11 April 2011
Fill in Yellow Blocks and Select Buttons to Add Data to Summary List:

Name of Individual:	(1)	Col Joseph T. Washington
SSN (xxx-xx-xxxx):	(2)	123-23-1234
Date of Internal Monitoring (dd mmm yyyy)	(3)	01 Apr 2011
Reviewed by:	(4)	
Date Reviewed (dd mmm yyyy)	(5)	

SELECTION BUTTONS

Select to Add Info to Summary List and Clear Cells for Next Entry

Select Print Area for E600/ SPA3 Report

Select Print Area For Accu/ Fast Scan Report

SELECTION BUTTONS

Select To Erase Summary Data Sheet. CAREFUL MAKE SURE YOU WANT TO ERASE!

Select to Populate Yellow Cells to the Left with Data Example 1.

Select to Populate Yellow Cells to the Left with Data Example 2.

Select to Populate Yellow Cells to the Left with Data Example 3.

E-600/SPA3 - Internal Monitoring (Yellow Highlighted Fields Require Entry):

The Number of Days Between First Exposure and Internal Monitoring	7
Measured Background CPM	4000

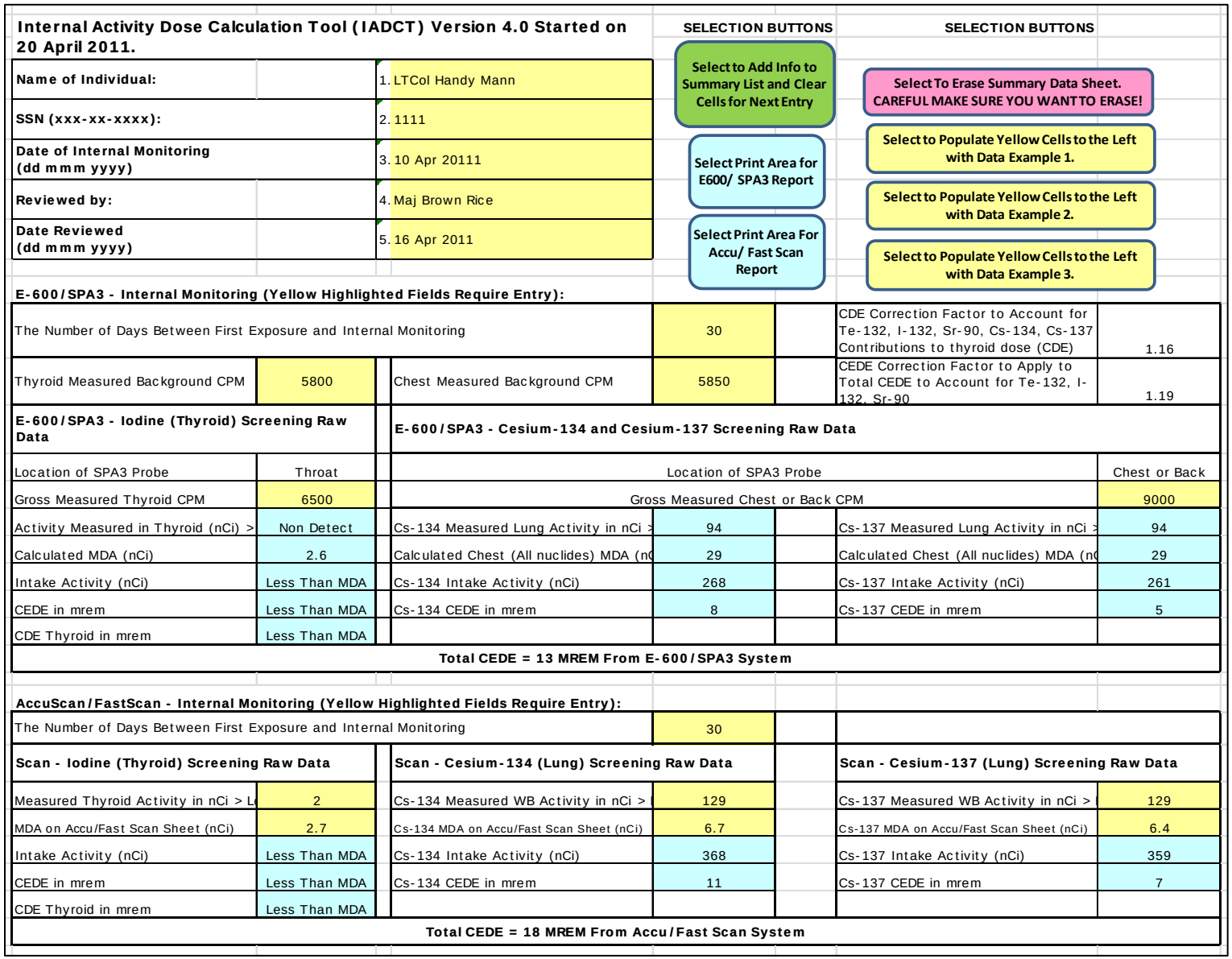
E-600/SPA3 - Iodine (Thyroid) Screening Raw Data			**E-600/SPA3 - Cesium (Lung) Screening Raw Data**	
Location of SPA3 Probe	Throat		Location of SPA3 Probe	Chest or Back
Measured Thyroid CPM	5000		Measured Chest or Back CPM	4500
Activity Measured in Thyroid (nCi)	6		Activity Measured in Lung (nCi)	89
Calculated MDA (nCi)	1		Calculated MDA (nCi)	14
Intake Activity (nCi)	77		Intake Activity (nCi)	2,126
CEDE in mrem	2		CEDE in mrem	36
CDE Thyroid in mrem	43			
Total CEDE = 38 mrem From E-600/SPA3 System				

AccuScan/FastScan - Internal Monitoring (Yellow Highlighted Fields Require Entry):

The Number of Days Between First Exposure and Internal Monitoring	7

Scan - Iodine (Thyroid) Screening Raw Data			**Scan - Cesium (Lung) Screening Raw Data**	
Measured Thyroid Activity in nCi	6		Measured Whole Body Activity in nCi	890
Calculated MDA (nCi)	1		Calculated MDA (nCi)	1
Intake Activity (nCi)	81		Intake Activity (nCi)	2,119
CEDE in mrem	2		CEDE in mrem	36
CDE Thyroid in mrem	45			
Total CEDE = 38 mrem From Accuscan System				

Figure 21. Screen shot of IADCT Version 1.0 operator's input tab



Internal Activity Dose Calculation Tool (IADCT) Version 4.0 Started on 20 April 2011.

SELECTION BUTTONS

Select to Add Info to Summary List and Clear Cells for Next Entry

Select Print Area for E600/ SPA3 Report

Select Print Area For Accu/ Fast Scan Report

SELECTION BUTTONS

Select To Erase Summary Data Sheet. CAREFUL MAKE SURE YOU WANT TO ERASE!

Select to Populate Yellow Cells to the Left with Data Example 1.

Select to Populate Yellow Cells to the Left with Data Example 2.

Select to Populate Yellow Cells to the Left with Data Example 3.

Name of Individual:	1. LTCol Handy Mann
SSN (xxx-xx-xxxx):	2. 1111
Date of Internal Monitoring (dd mmm yyyy)	3. 10 Apr 20111
Reviewed by:	4. Maj Brown Rice
Date Reviewed (dd mmm yyyy)	5. 16 Apr 2011

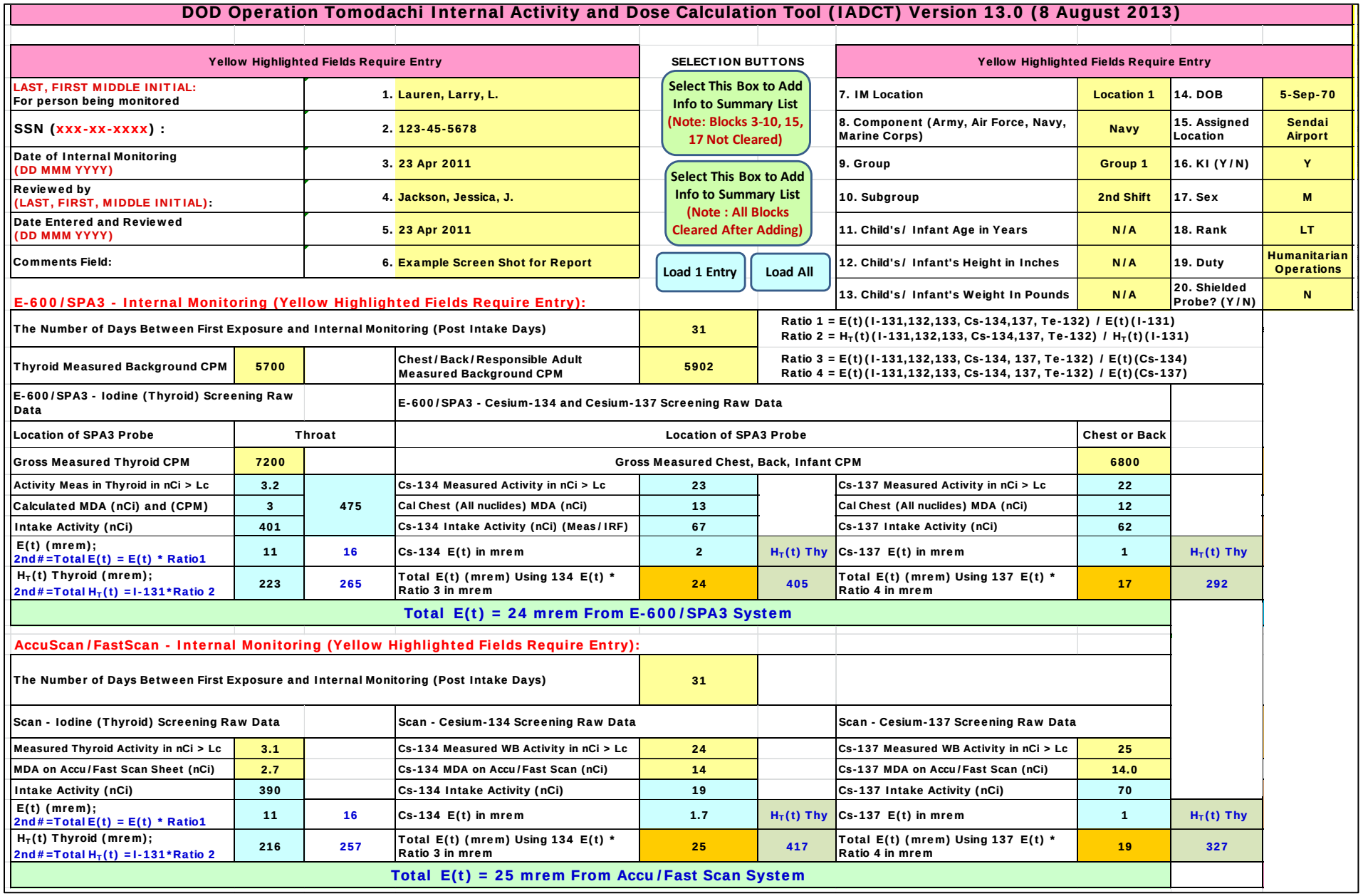
E-600/SPA3 - Internal Monitoring (Yellow Highlighted Fields Require Entry):

The Number of Days Between First Exposure and Internal Monitoring				30		CDE Correction Factor to Account for Te-132, I-132, Sr-90, Cs-134, Cs-137 Contributions to thyroid dose (CDE)	1.16
Thyroid Measured Background CPM	5800		Chest Measured Background CPM	5850		CEDE Correction Factor to Apply to Total CEDE to Account for Te-132, I-132, Sr-90	1.19
E-600/SPA3 - Iodine (Thyroid) Screening Raw Data			**E-600/SPA3 - Cesium-134 and Cesium-137 Screening Raw Data**				
Location of SPA3 Probe	Throat		Location of SPA3 Probe				Chest or Back
Gross Measured Thyroid CPM	6500		Gross Measured Chest or Back CPM				9000
Activity Measured in Thyroid (nCi) >	Non Detect		Cs-134 Measured Lung Activity in nCi >	94		Cs-137 Measured Lung Activity in nCi >	94
Calculated MDA (nCi)	2.6		Calculated Chest (All nuclides) MDA (nC	29		Calculated Chest (All nuclides) MDA (nC	29
Intake Activity (nCi)	Less Than MDA		Cs-134 Intake Activity (nCi)	268		Cs-137 Intake Activity (nCi)	261
CEDE in mrem	Less Than MDA		Cs-134 CEDE in mrem	8		Cs-137 CEDE in mrem	5
CDE Thyroid in mrem	Less Than MDA						
Total CEDE = 13 MREM From E-600/SPA3 System							

AccuScan/FastScan - Internal Monitoring (Yellow Highlighted Fields Require Entry):

The Number of Days Between First Exposure and Internal Monitoring				30			
Scan - Iodine (Thyroid) Screening Raw Data			**Scan - Cesium-134 (Lung) Screening Raw Data**			**Scan - Cesium-137 (Lung) Screening Raw Data**	
Measured Thyroid Activity in nCi > L	2		Cs-134 Measured WB Activity in nCi >	129		Cs-137 Measured WB Activity in nCi >	129
MDA on Accu/Fast Scan Sheet (nCi)	2.7		Cs-134 MDA on Accu/Fast Scan Sheet (nCi)	6.7		Cs-137 MDA on Accu/Fast Scan Sheet (nCi)	6.4
Intake Activity (nCi)	Less Than MDA		Cs-134 Intake Activity (nCi)	368		Cs-137 Intake Activity (nCi)	359
CEDE in mrem	Less Than MDA		Cs-134 CEDE in mrem	11		Cs-137 CEDE in mrem	7
CDE Thyroid in mrem	Less Than MDA						
Total CEDE = 18 MREM From Accu/Fast Scan System							

Figure 22. Screen shot of IADCT Version 4.0 operator's input tab



DOD Operation Tomodachi Internal Activity and Dose Calculation Tool (IADCT) Version 13.0 (8 August 2013)

Yellow Highlighted Fields Require Entry		SELECTION BUTTONS	Yellow Highlighted Fields Require Entry			
LAST, FIRST MIDDLE INITIAL: For person being monitored	1. Lauren, Larry, L.	Select This Box to Add Info to Summary List (Note: Blocks 3-10, 15, 17 Not Cleared)	7. IM Location	Location 1	14. DOB	5-Sep-70
SSN (xxx-xx-xxxx) :	2. 123-45-5678		8. Component (Army, Air Force, Navy, Marine Corps)	Navy	15. Assigned Location	Sendai Airport
Date of Internal Monitoring (DD MMM YYYY)	3. 23 Apr 2011	Select This Box to Add Info to Summary List (Note : All Blocks Cleared After Adding)	9. Group	Group 1	16. KI (Y/N)	Y
Reviewed by (LAST, FIRST, MIDDLE INITIAL):	4. Jackson, Jessica, J.		10. Subgroup	2nd Shift	17. Sex	M
Date Entered and Reviewed (DD MMM YYYY)	5. 23 Apr 2011		11. Child's/ Infant Age in Years	N/A	18. Rank	LT
Comments Field:	6. Example Screen Shot for Report	Load 1 Entry / Load All	12. Child's/ Infant's Height in Inches	N/A	19. Duty	Humanitarian Operations
			13. Child's/ Infant's Weight In Pounds	N/A	20. Shielded Probe? (Y/N)	N

E-600/SPA3 - Internal Monitoring (Yellow Highlighted Fields Require Entry):

The Number of Days Between First Exposure and Internal Monitoring (Post Intake Days)			31		Ratio 1 = E(t)(I-131,132,133, Cs-134,137, Te-132) / E(t)(I-131) Ratio 2 = H_T(t)(I-131,132,133, Cs-134,137, Te-132) / H_T(t)(I-131)			
Thyroid Measured Background CPM	5700		Chest/Back/Responsible Adult Measured Background CPM	5902	Ratio 3 = E(t)(I-131,132,133, Cs-134, 137, Te-132) / E(t)(Cs-134) Ratio 4 = E(t)(I-131,132,133, Cs-134, 137, Te-132) / E(t)(Cs-137)			
E-600/SPA3 - Iodine (Thyroid) Screening Raw Data			E-600/SPA3 - Cesium-134 and Cesium-137 Screening Raw Data					
Location of SPA3 Probe	Throat		Location of SPA3 Probe			Chest or Back		
Gross Measured Thyroid CPM	7200		Gross Measured Chest, Back, Infant CPM			6800		
Activity Meas in Thyroid in nCi > Lc	3.2		Cs-134 Measured Activity in nCi > Lc	23		Cs-137 Measured Activity in nCi > Lc	22	
Calculated MDA (nCi) and (CPM)	3	475	Cal Chest (All nuclides) MDA (nCi)	13		Cal Chest (All nuclides) MDA (nCi)	12	
Intake Activity (nCi)	401		Cs-134 Intake Activity (nCi) (Meas/IRF)	67		Cs-137 Intake Activity (nCi)	62	
E(t) (mrem); 2nd#=Total E(t) = E(t) * Ratio1	11	16	Cs-134 E(t) in mrem	2	H_T(t) Thy	Cs-137 E(t) in mrem	1	H_T(t) Thy
H_T(t) Thyroid (mrem); 2nd#=Total H_T(t) =I-131*Ratio 2	223	265	Total E(t) (mrem) Using 134 E(t) * Ratio 3 in mrem	24	405	Total E(t) (mrem) Using 137 E(t) * Ratio 4 in mrem	17	292
Total E(t) = 24 mrem From E-600/SPA3 System								

AccuScan/FastScan - Internal Monitoring (Yellow Highlighted Fields Require Entry):

The Number of Days Between First Exposure and Internal Monitoring (Post Intake Days)			31					
Scan - Iodine (Thyroid) Screening Raw Data			Scan - Cesium-134 Screening Raw Data			Scan - Cesium-137 Screening Raw Data		
Measured Thyroid Activity in nCi > Lc	3.1		Cs-134 Measured WB Activity in nCi > Lc	24		Cs-137 Measured WB Activity in nCi > Lc	25	
MDA on Accu/Fast Scan Sheet (nCi)	2.7		Cs-134 MDA on Accu/Fast Scan (nCi)	14		Cs-137 MDA on Accu/Fast Scan (nCi)	14.0	
Intake Activity (nCi)	390		Cs-134 Intake Activity (nCi)	19		Cs-137 Intake Activity (nCi)	70	
E(t) (mrem); 2nd#=Total E(t) = E(t) * Ratio1	11	16	Cs-134 E(t) in mrem	1.7	H_T(t) Thy	Cs-137 E(t) in mrem	1	H_T(t) Thy
H_T(t) Thyroid (mrem); 2nd#=Total H_T(t) =I-131*Ratio 2	216	257	Total E(t) (mrem) Using 134 E(t) * Ratio 3 in mrem	25	417	Total E(t) (mrem) Using 137 E(t) * Ratio 4 in mrem	19	327
Total E(t) = 25 mrem From Accu/Fast Scan System								

Figure 23. Screen shot of IADCT Version 13.0 operator's input tab

Section 7.

Quality Assurance

Quality assurance elements and methodologies were used throughout the IM process to ensure that the calculated doses were accurate. This section discusses the following quality assurance elements:

- Development of the algorithm and IADCT
- Implementation of radiological controls
- Daily quality assurance checks on equipment
- Establishment of a SM during internal monitoring operations
- Daily review of IM results from a central authority
- Post assessment of input and results

7.1 Development of the Algorithm and IADCT

The scientific methods and the IADCT used to convert the activity measurements to doses were reviewed and/or approved by several individuals during the implementation of the initial version during March 2011. These individuals were a U.S. Army health physicist serving at USPACOM, Camp Smith, HI; the U.S. Navy medical physicist stationed at the Uniform Services University of the Health Sciences in Bethesda, MD; the Manager of Radiological Health at KAPL, Schenectady, NY; and the Radiological Health Director for the Naval Nuclear Propulsion Program, Washington, DC. IADCT calculations were also verified with manual sample calculations to confirm that the spreadsheet produced the expected result. The results were also compared to an independent calculation performed by KAPL using the same assumptions. This provided a high degree of assurance that both the methods and implementation were being done correctly.

The initial release of IADCT (Version 1.0) was revised 12 times to:

- add functionality to accommodate more demographic information;
- increase conservatism by accounting for all nuclides independently measured in air samples but not detected by internal monitoring;
- increase the sophistication of the calculations by adding age dependence; and
- fix minor problems that were discovered during conduct of the IM program, such as reporting that a value was measurable above the critical value but less than the MDA.

The first tab on the IADCT was used to document the changes that were made on each revision. All the measurement data were rerun through the algorithm each time a revision was made and results were validated with manual sample calculations to verify that the spreadsheet was producing the result expected.

7.2 Implementation of Radiological Controls

High background radiation around IM areas and contamination on monitored personnel were discovered to be occasional problems, and it became apparent that good radiological controls and methods would be necessary for quality assurance and to obtain valid IM results. During the first two days of IM (April 12–13, 2011), 36 people were internally monitored at the Atsugi NAF with both portable and fixed units. Many of these people were unknowingly wearing clothing with low levels of surface contamination that confounded the results on these days. Consequently, none of these measurements were used and all the people monitored on these days were re-measured. It was observed that very small amounts of contamination on clothing caused a large response on the portable units primarily because of the minimal distance (essentially zero) between the source and detector. The effects of low levels of contamination were not as pronounced on the fixed units because the distances between the source and detector were greater than on the portable units.

Following the realization that portable instrument scans could easily be confounded by trace amounts of radioactive contamination on clothing, the procedures were changed to require personnel to be in physical training gear or other clothing not used in the field to avoid contamination from clothing such as discovered on flight suits, even after they had been laundered. Any persons with results that were greater than the MDA were asked to put on clean Tyvek® clothing and were asked to be re-monitored. The use of Tyvek clothing by individuals participating in OT RIMIS is shown in Figure 24.

Figure 24. Tyvek clothing worn by monitored individuals in the OT RIMIS program

Starting on April 14, 2011, operations were restarted with increased radiological controls as part of the quality assurance program. All individuals to be internally monitored were asked to come in with clean physical training clothes and any individuals with results greater than the MDA were asked to put on new clean Tyvek clothing and were re-monitored. There were four

individuals who had measured internal activities greater than the MDA on both portable and fixed units and with approximately equal amounts of Cs-134 and Cs-137 as spectrometrically measured on the fixed scanners. These measurements were used to correlate the portable instruments for cesium whole body measurements. Beginning on April 14, stricter radiological controls were put into force and the HP Directive was revised to include these quality assurance steps. For example, a survey instrument was used to monitor in and around IM areas and sticky pads were placed in entrances to catch any low level contamination on the shoes of persons entering the internal monitoring facility.

Prior to establishing an appropriate location for internal monitoring in the operational field, survey measurements were taken and the lowest possible background locations were chosen to keep the MDA for the portable instruments as low as possible. Additionally, surveys were taken at the beginning and end of each 8-hour shift to ensure that background radiation levels were not changing significantly. This was an important quality assurance element because any change in background rate would invalidate the IM measurement because background measurement taken at the beginning of the day was subtracted from all IM measurements taken over the entire 8-hour shift. In addition, care was taken to perform IM in areas where there was minimal electromagnetic interference as this could be another source of anomalous results.

7.3 Daily Quality Assurance Checks on Equipment

Fixed units went through the standard quality assurance checks that were part of the normal radiological controls program used by the NNPP because these units were always operated by a Navy civilian employee who was an NNPP-trained and qualified staff member. Portable units were turned on and allowed to warm up and stabilize before use. Each SPA-3 probe was mounted on a stand and fixed in position at the beginning of each shift so that there were no changes in geometry and location within the environment. This helped to reduce variability and was implemented as a quality control measure. Background measurements were done in multiple configurations at the beginning and end of the shift for quality control purposes. The three configurations were FAC, on the chest (on the back if females were to be monitored during that shift), and on the throat at the thyroid. This was done so that ratios of measurements could be taken between throat/chest/back and FAC and compared between different instruments. Anomalous ratios served to initiate an investigation of the measurements taken with that instrument. Additionally, by taking measurements at the beginning and end of the day the instrument could be evaluated for potential problems. When beginning and end measurements were found to differ by more than 10 percent, an investigation was undertaken to explain the differences or those measurements were re-taken.

7.4 Establishment of a Site Manager during Internal Monitoring Operations

The concept of a SM was established for OCONUS IM to ensure that operations were being performed according to the approved directives and that data were being correctly reviewed and input on a real time basis. Every location where IM was performed was required to have an OT RIMIS program-trained and certified SM to oversee the team conducting IM. There were three fixed locations and many temporary locations established in the theater of operations, including on many ships. CONUS operations were under direction of the site Radiation Health Director/ Manager.

SMs were familiar with pertinent policy and procedure documents listed in Section 1.5 of this report. Each SM received training with an OT RIMIS program expert regarding expectations for briefing and monitoring the personnel who performed the IM at their location. The training would include lessons learned from previous internal monitoring sessions, responses for questions likely to arise during monitoring (from personnel being monitored and also from personnel operating the equipment), the set up of the location where personnel were monitored, the methods to control and protect personal information, and familiarization of the systems and equipment to be used at their location. The SM training was documented on a standard form and uploaded to the DOEHS data portal.

Each day prior to the start of the first shift, individual SMs contacted the Yokosuka NB SM to receive updates and to provide a status of sites. If the SM at Yokosuka NB could not be reached, then the individual SM was required to contact the Joint Support Forces-Japan Surgeon's Office or the USPACOM Surgeon's Office. This ensured rapid dissemination of IADCT algorithm and instruction versions and lessons learned feedback. At the end of each day, the SM was required to review all the data and results from that day and send a daily QA sheet to the SM at Yokosuka NB.

In addition, SMs were responsible for ensuring:

- That the ACCUSCAN II, FASTSCAN and E-600/SPA-3 systems were ready for use and that the operators had performed all the daily quality assurance procedures using the most current versions before beginning IM during each shift.
- That individuals acting as E-600/SPA-3 clean human phantoms were verified to be free of internal, reactor-generated radioactivity using a fixed whole body counter and that copies of the whole body counter output are attached to one of the E-600/SPA-3 background datasheets for record keeping purposes.
- That all background measurements were correctly taken at the beginning and end of the shift, reviewed, recorded on the Background Data Sheet, and uploaded to the DOEHS Data Portal at the end of the day.
- That local radiological controls were implemented to include:
  - Ensuring that the spaces and equipment used for internal monitoring were maintained as free as possible from environmental radioactive contamination,
  - That surveys and wipe downs of equipment were conducted frequently, and
  - That sticky pads were used at the entrance of the counting space(s) and ACCUSCAN II/ FASTSCAN entrance areas to minimize the entry of radioactivity into the spaces and equipment.
- That each monitored individual's information and measurements were correctly entered into the IADCT spreadsheet and that information on the paper data sheets was verified by the monitored individual as legible and correct as indicated by their initials on the form.
- That the date for first exposure was the date that the individual was first exposed to a plume (if known) or the date of arrival in theater (if plume exposure date was unknown).
- That individuals who were scanned answered questions regarding their use of potassium iodide while in theater.

7.5 Daily Review of Internal Monitoring Results from a Central Authority

Each day, the SM at each location ensured that paper datasheets were scanned into PDF documents. These files and the IADCT spreadsheet were uploaded to the DOEHS data portal on a daily basis except in those cases where it was not possible during field operations. DOEHS served as a temporary data repository and link to USPACOM oversight management at Camp Smith in Hawaii and the NDC in Bethesda, Maryland. Each day either the USPACOM or NDC management downloaded the files for local storage and review of the data. Any issues of concern were discussed and resolved the following day during the daily brief between USPACOM and the SM at Yokosuka NB, who then passed information to each site SM. This system provided for an almost real-time feedback and correction system, and it was an important quality design feature of the process.

7.6 Post Assessment of Input and Results

After OT was completed, the DARWG arranged for a team of one U.S. Army officer and two U.S. Navy enlisted personnel to perform a data validation of all the IM data under the authority of the NDC. It was estimated that about 1,700 labor hours were expended to fulfill the data validation that included checking the electronic data with the paper data ensuring that correct demographic data, dates of internal monitoring, and count data had been entered. All paper records were then scanned into electronic files and uploaded into the web-based search and retrieval content management system ArchivalWare™ (Progressive Technology Federal Systems, Inc.). This will allow for easy retrieval of information if individual dose investigations are performed in the future.

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Section 8.

Results and Discussion

8.1 Results

8.1.1. Measurements and Doses

As shown in Table 25, 8,378 individual IM measurements were made on DOD-affiliated individuals because of their involvement with OT. Generally, IM measurements from people who were already part of an established occupational radiation monitoring program were not included in these results. However, some people where being monitored in an occupational surveillance program might have been monitored unitentionally as part of the OT RIMIS program. Of the 8,378 individual measurements, 946 (11%) were done in CONUS on fixed scanners located at Naval facilities in the United States. There were 7,277 (87%) IM measurements done at OCONUS locations as part of the Operational Monitoring, and 155 (2%) done at OCONUS locations as part of the Open Availability Monitoring. Activities greater than the MDA were detected for 238 (3%) measurements of which 104 (44%) were observed in the CONUS measurements and 134 (56%) in the OCONUS operational measurements.

The maximum, mean, and minimum committed doses, as well as the monitoring periods for each of the IM phases (CONUS, OCONUS Operational, OCONUS Open Availability) are shown in Table 26. Doses calculated with measured activities greater than the MDA resulted in a maximum committed effective dose of 0.25 mSv (0.025 rem) and a maximum committed equivalent dose to the thyroid of 4.2 mSv (0.42 rem) (see Table 26). Relative and cumulative frequency distributions of the doses that were calculated for activity values greater than the MDA are provided in Figure 25 through Figure 28. Those four figures indicate that most of the doses are at the lower values, which is typical for the distributions of environmental exposure results.

During the OCONUS, Open Availability phase, none of the 155 people monitored had measured activities greater than the MDA. The 155 people comprised 51 children, 46 dependent adults, 38 DOD civilian and contractor employees, and 20 active duty personnel.

Table 25. Summary OT RIMIS statistics for three IM phases

	All Internally Monitored Individuals		Monitoring Results Greater than MDA		
IM Phase	**Number of Individual Measurements**	**Percent of Total**	**Number of Individual Measurements**	**Percent of Total**	**Percent of those Greater than MDA**
CONUS	946	11	104	1.2	44
OCONUS, Operational	7,277	87	134*	1.6	56
OCONUS, Open Availability	155	2	0	0	0
Total	8,378	100	238	2.8	100

* There were 134 thyroid equivalent dose measurements (131 effective dose measurements) during the OCONUS, Operational phase that included five measurements that were greater than the MDAs for both thyroid and effective doses, on both fixed and portable systems.

Table 26. Characterization of IM doses greater than MDA for three IM phases

IM Phase	Dose Statistic	Committed Effective Dose (mSv [rem])	Committed Equivalent Dose to the Thyroid (mSv [rem])	Dates (2011) of Measurements > MDA	
				Earliest Date	Latest Date
CONUS, Mar 16– May 19, 2011	Maximum	0.05 [0.005]	0.77 [0.077]	Mar 16	Apr 11
	Mean	0.02 [0.002]	0.34 [0.034]		
	Minimum	0.01 [0.001]	0.09 [0.009]		
OCONUS, Operational, Apr 14– Aug 31, 2011	Maximum	0.25 [0.025]	4.2 [0.42]	Apr 14	Aug 10
	Mean	0.06 [0.006]	1.0 [0.10]		
	Minimum	0.02 [0.002]	0.29 [0.029]		
OCONUS, Open Availability, Jul 26– Aug 31, 2011	Maximum	N/A*	N/A	N/A	N/A
	Mean				
	Minimum				

* N/A indicates "Not Applicable", i.e., there were no IM results (activities) greater than the MDA.

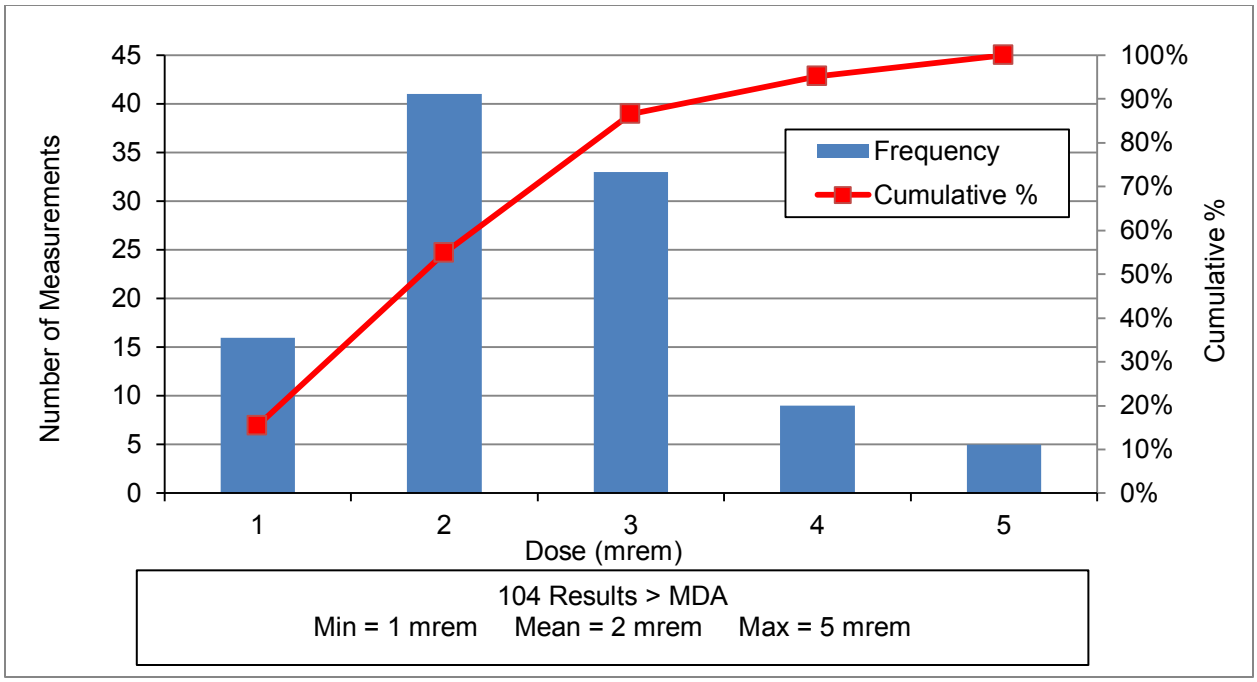

Figure 25. Distribution of committed effective doses for measured activities greater than the MDA (In CONUS)

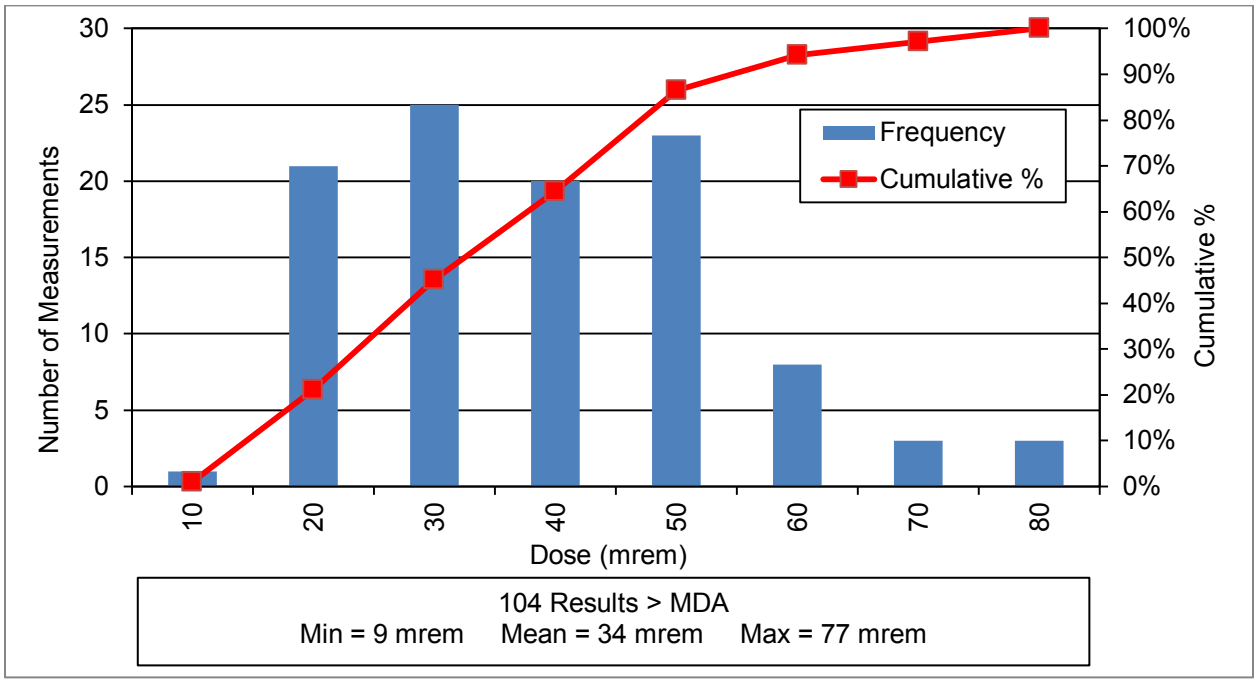

Figure 26. Distribution of committed equivalent doses to the thyroid for measured activities greater than the MDA (In CONUS)

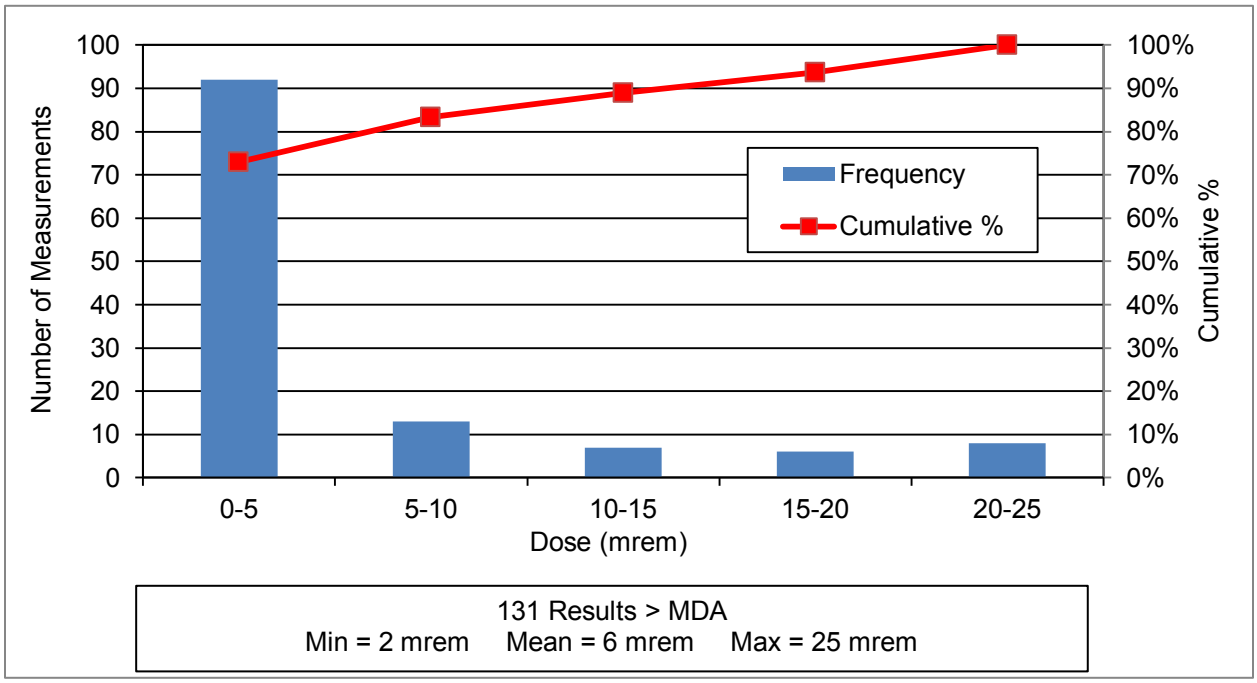

Figure 27. Distribution of committed effective doses for measured activities greater than the MDA (OCONUS)

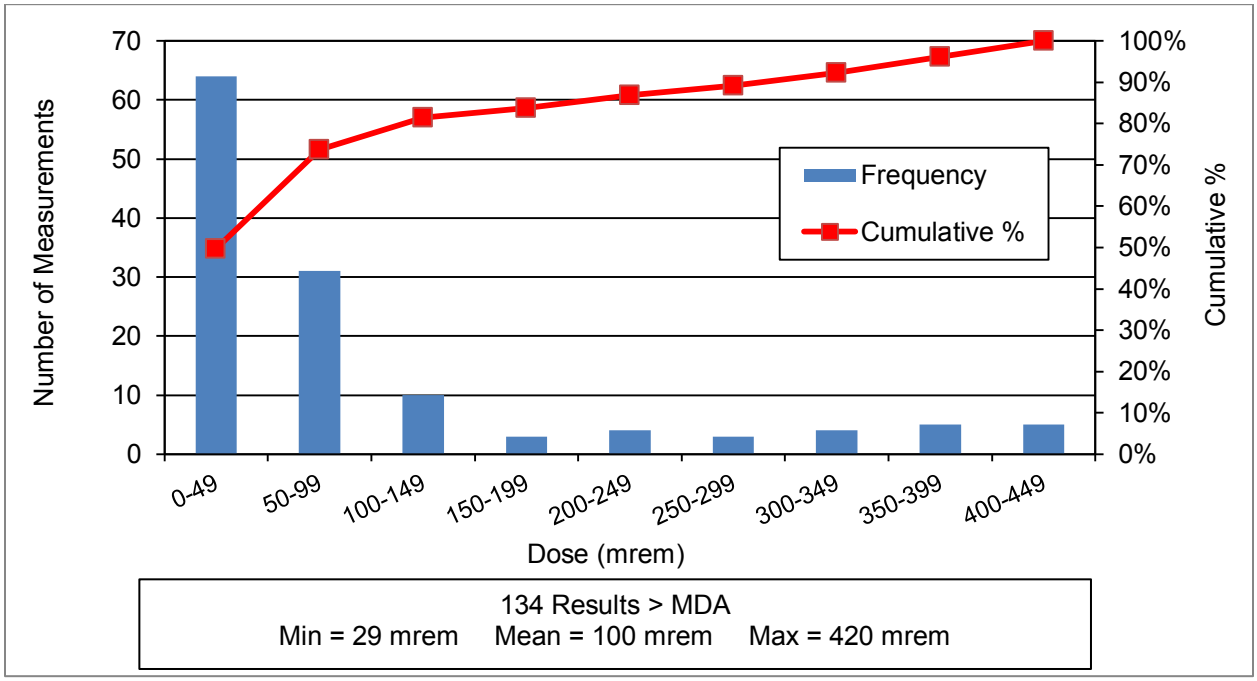

Figure 28. Distribution of committed equivalent doses to the thyroid for measured activities greater than the MDA (OCONUS)

8.1.2. Timeliness of IM Measurements

The timely assessment of intake of radioactive materials resulting in internal contamination of individuals was accomplished. Individuals were prioritized by first identifying and conducting IM on those individuals with the highest potential for internal contamination. This was later expanded to include everyone who could be measured at specific site visited, and finally to include anyone who desired to be monitored from any site or location. There was excess IM capacity and monitoring was not limited by the amount of equipment or availability of operators. The capability to use both fixed scanners and portable instruments ensured that enough individuals in different cohorts were monitored. The populations with the highest potential intake would include, for example, those performing humanitarian work in areas of elevated contamination, those performing decontamination operations of equipment, and those traveling through known plumes. These populations should be monitored on the earliest possible date and again at regular intervals.

Individuals were provided with an interpretation of their IM measurements immediately after their monitoring was completed. This was possible because of the automated IADCT workbook, which allowed for a real-time evaluation of the measured activity. The individual was given one of three prepared responses rather than an actual dose value (number). USPACOM health physicists and risk communicators determined that dose values would not be meaningful to the person monitored and that the values could change slightly if different assumptions were made or different IADCT versions created in future re-evaluations. This approach was effective and should be used for population monitoring events in the future.

The distribution of IM measurements as a function of time is shown in Figure 29. IM dates ranged from 5 to 171 days after March 11, 2011, which was the assumed intake date for IM measurements when nothing else was known about possible date(s) of intakes for the individual being monitored. For 78 percent of the measurements, a case-specific value for the approximate date of intake was used. This means that the most conservative value for intake date of March 11, 2011, was assumed for the remaining 22 percent of the measurements.

As shown in Figure 29, approximately 60 percent of the measurements were completed by mid-May 2011, which was about two months after the periods of highest air activity concentrations and their associated potentially high intakes. This means that operational commanders and, more importantly, individuals, received information about their possible exposures to internal organs and tissues at a time when concerns for their safety were still high. Of particular note is the successful implementation of IM in Japan using an innovative combination of fixed, full body scanners and portable instruments to provide 7,432 measurements.

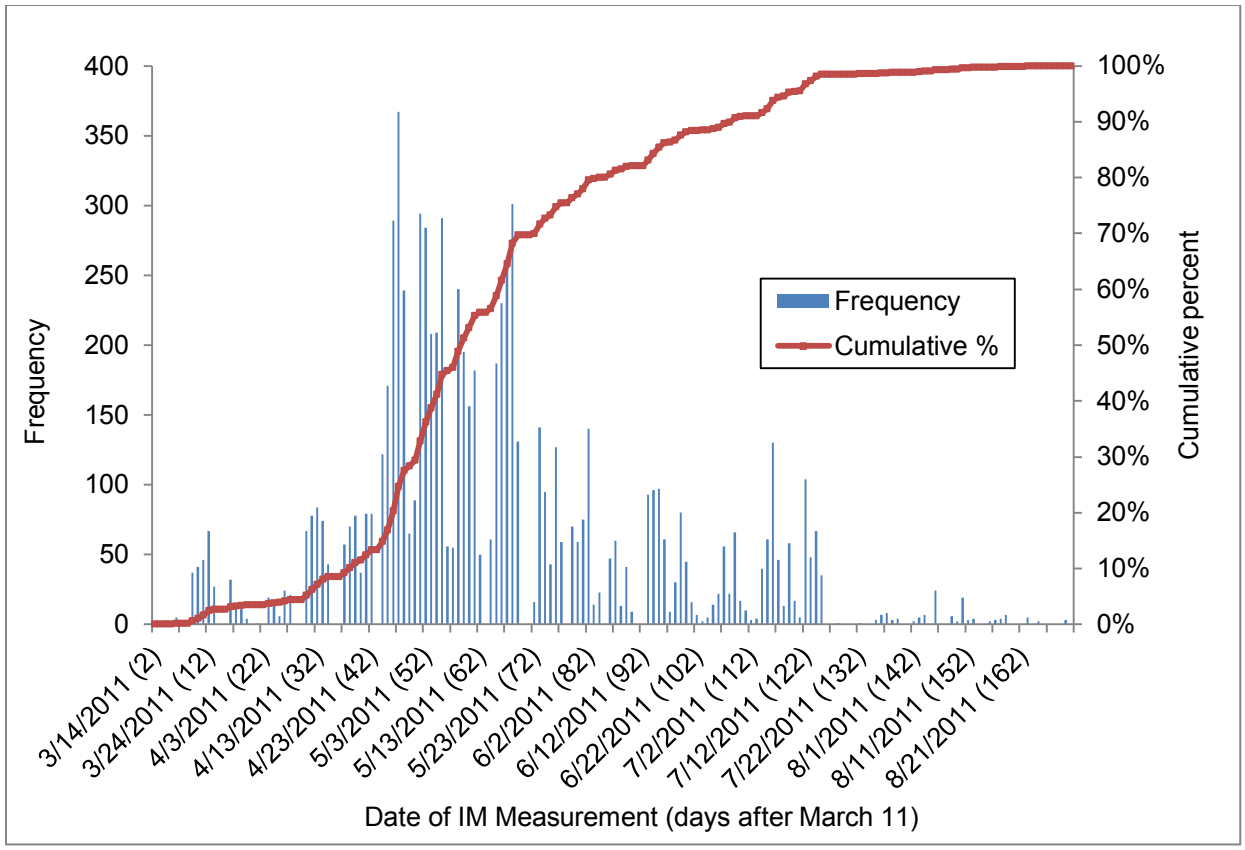

Figure 29. Frequency and cumulative probability distributions of the numbers of individuals monitored by date and days after March 11, 2011

The distribution of IM measurements with time as shown in Figure 29 raises the question of the ideal time between intake and monitoring, for which the answer is perhaps as soon as possible after the end of intake. Several assumptions were made about the date of intake in the OT RIMIS assessments. For example, all intakes were assumed to occur on a single day. However, in the majority of OT intake situations, intakes would be more likely to occur during more than one day because airborne radioactive plumes may persist for longer than one day. In general (i.e., not taking into account any specific individual and their unique exposure situation), the majority of intakes during OT would have occurred on those days where maximum peak air activity concentrations occurred. For individuals at locations in the Kanto Plain region (e.g., Yokota AB), two distinct peaks in air activity concentration occurred from March 13–16 and March 19–22. These peaks for Cs-134 can be seen in Figure 30 and are typical of the patterns observed for other radionuclides present at the time, such as Cs-137, Te-132, I-131, I-132, and I-133. The ideal time to monitor a person breathing air with the air activity concentration pattern shown in Figure 30 would depend on when the person was removed from the location (i.e., breathing the contaminated air stops), the nuclides of concern (for example the effective half-lives for I-131, Cs-134, and Cs-137 are 7.5 d, 96 d, and 109 d, respectively), and the number of measurements that can be made—the vast majority of individuals monitored in the OT RIMIS program had one measurement.

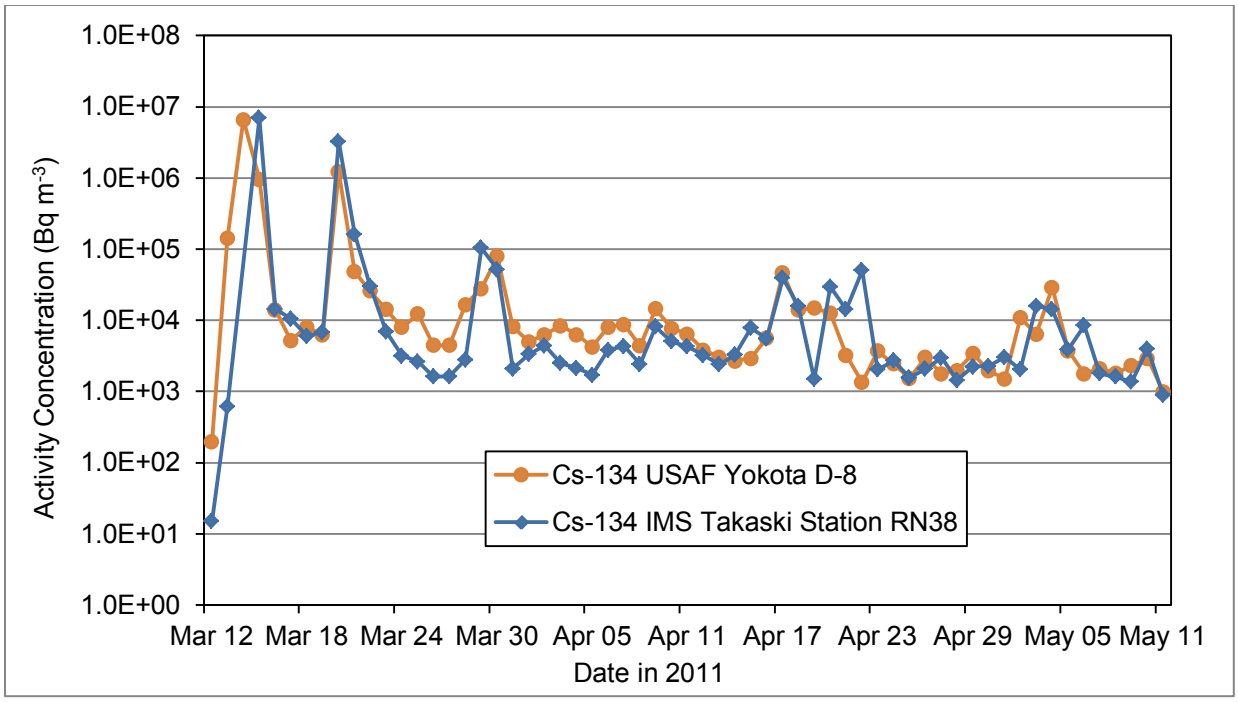

Figure 30. Measured Cs-134 air concentrations at Yokota AB (D-8) and IMS Takasaki Station RN38

IM measurements taken too early or too late (relative to peak air activity concentrations) could have resulted in missing some intake. Generally, once a person was no longer subjected to the contaminated environment, the ideal time to measure them would be within a few days. Ideally, individuals who continued to operate in a contaminated environment following an air activity concentration peak should have been monitored within a few days after each large peak has passed. If each individual was only measured once, then monitoring should have taken place as soon after the last large peak had passed (assuming information of the timing of air activity concentration peaks was available). Unfortunately, there is no ideal answer because of the dependence on the specific details of an individual exposure scenario.

For the OT IM measurements, intake was conservatively assumed to occur during a single episode on the earliest possible day, and most measurements were performed well after the largest peaks had passed. In addition, since both whole body and thyroid measurements were made, the longer-lived radioisotopes of cesium were detected for any significant intakes even if all of the shorter-lived iodine isotope I-131 had decayed away. As a rule of thumb, it is generally assumed that the radioisotope is effectively no longer present in the body at significant concentrations after 10 effective half lives of the radioisotope have passed. For I-131, 10 effective half lives is 75 days from intake. From Figure 29, it is apparent that all measurements were made within two effective half lives of both Cs-134 and Cs-137. Therefore, the OT IM timing of measurements and assumed intakes were such that any significant intakes of radionuclides would have been detected.

8.2 Discussion

8.2.1. Comparison with Doses Reported for Shore-based Individuals

In its dose assessment report for shore-based individuals Cassata et al. (2012), DARWG reported conservative doses for individuals in 13 potentially exposed populations (PEPs) of adults (humanitarian relief) as shown in Table 27 and Table 28. The maximum measured IM values from individuals from Table 26 are 0.25 mSv (0.025 rem) committed whole body effective dose and 4.2 mSv (0.42 rem) committed equivalent dose to the thyroid. The corresponding values from Cassata et al. (2012) are 0.79 mSv (0.079 rem) committed effective dose and 12 mSv (1.2 rem) committed equivalent dose to the thyroid at Sendai Airport. The IM results are about a factor three less than the calculated values from cohort populations, which is reassuring since the calculated values are based on conservative assumptions and were shown to be greater than the 95th percentile doses in Chehata et al. (2013). These comparisons are for adult humanitarian workers at all locations considered by DARWG.

Comparisons of location-specific individual IM results with the location-specific PEP doses was complicated because the location(s) at which an individual may have been exposed was difficult to accurately determine. This information was needed to accurately correlate the specific PEP location doses with individual IM measurement results. The procedure for conducting IM measurements included the requirements to record where the IM measurement was taken, to ask individuals about their work location and the location at which they may have been exposed, and to enter the information into the IADCT workbook. However, individuals didn't necessarily know where they might have been exposed and sometimes found it difficult to describe where they had worked, especially if they had worked at several different locations. Sometimes the IM location was the same as the work and potential exposure location. For example, an IM location at Yokosuka NB would likely be the work location and the potential exposure location for an individual assigned to Yokosuka NB. In this case it was feasible to directly compare IM doses with those reported in Cassata et al. (2012).

8.2.2. IM Results for Fleet and Air Crews

Of the total 7,947 individuals internally monitored, roughly one-half were fleet and air crew individuals and one-half were shore based individuals. The percentage of fleet and air crew internally monitored was about 25 percent based on an estimate of 17,000 total fleet and aircrew individuals involved with OT (Cassata et. al., 2012). The percentage of shore-based individuals internally monitored was about eight percent based on an estimate of 53,000 total shore-based personnel. Table 29 shows the breakdown of fleet and air crew individuals by ship and work location as well as the number of people monitored, the number of individuals with doses greater than zero, and the maximum and average effective and thyroid doses.

Table 27. Committed effective doses for adults (humanitarian relief) for DARWG PEP locations

DARWG Location (No.)	Committed Effective Doses by Intake Pathway[*,†]							
	Air Inhalation		Water Ingestion		Soil Ingestion		Total	
	rem	mSv	rem	mSv	rem	mSv	rem	mSv
Misawa AB (D-1)	<0.001	<0.01	<0.001	<0.01	<0.001	<0.01	<0.001	<0.01
Sendai Airport (D-2)	0.039	0.39	0.040	0.4	<0.001	<0.01	0.079	0.790
City of Ishinomaki (D-3)	0.021	0.21	0.030	0.3	<0.001	<0.01	0.051	0.510
Hyakuri AB (D-6)	0.021	0.21	<0.001	<0.01	<0.001	<0.01	0.021	0.210
City of Oyama (D-7)	0.034	0.34	0.017	0.17	<0.001	<0.01	0.051	0.510
Yokota AB (D-8)[‡]	0.037	0.37	0.026	0.26	<0.001	<0.01	0.063	0.630
Akasaka Press Center (D-9)[‡]	0.018	0.18	0.010	0.1	<0.001	<0.01	0.028	0.280
Atsugi NAF (D-10)[‡]	0.018	0.18	0.010	0.1	<0.001	<0.01	0.028	0.280
Yokosuka NB (D-11)[‡]	0.018	0.18	0.003	0.03	<0.001	*<0.01*	0.021	0.210
Camp Fuji (D-12)	0.018	0.18	0.003	0.03	<0.001	<0.01	0.021	0.210
Iwakuni MCAS (D-13)	0.009	0.09	<0.001	<0.01	<0.001	<0.01	0.009	0.090
Sasebo NB (D-14)	0.001	0.01	<0.001	<0.01	<0.001	<0.01	0.001	0.010

[*] Doses were calculated based on conservative assumptions resulting in PEP doses that were greater than the 95th percentile values from the probabilistic dose analysis (Cassata et al., 2012; Chehata et al., 2013).

[†] These PEP doses were calculated assuming no time indoors and extremely high physical activity levels.

[‡] Dose contributions from air inhalation at these sites were calculated using Yokota AB air concentration data.

Table 28. Thyroid doses for adults (humanitarian relief) under maximum exposure conditions

DARWG Location (No.)	External Radiation[*,†]		Air Inhalation[*,†]		Water Ingestion[*,†]		Soil Ingestion[*,†]		Total[*,†]	
	rem	mSv	rem	mSv	rem	mSv	rem	mSv	rem	mSv
Misawa AB (D-1)	0.006	0.06	<0.001	<0.01	<0.001	<0.01	0.001	0.01	0.007	0.07
Sendai Airport (D-2)	0.039	0.39	0.59	5.9	0.59	5.9	<0.001	<0.01	1.2	12
City of Ishinomaki (D-3)	0.029	0.29	0.19	1.9	0.28	2.8	0.002	0.02	0.50	5
City of Yamagata (D-4)	0.015	0.15	0.43	4.3	<0.001	<0.01	0.002	0.02	0.45	4.5
Hyakuri AB (D-6)	0.023	0.23	0.68	6.8	0.30	3	0.004	0.04	1.0	10
City of Oyama (D-7)	0.025	0.25	0.73	7.3	0.38	3.8	0.004	0.04	1.1	11
Yokota AB (D-8)[‡]	0.027	0.27	0.33	3.3	0.17	1.7	0.001	0.01	0.53	5.3
Akasaka Press Center (D-9)[‡]	0.018	0.18	0.33	3.3	0.17	1.7	0.001	0.01	0.52	5.2
Atsugi NAF (D-10)[‡]	0.018	0.18	0.33	3.3	0.061	0.61	0.001	0.01	0.41	4.1
Yokosuka NB (D-11)[‡]	0.012	0.12	0.33	3.3	0.061	0.61	0.001	0.01	0.40	4
Camp Fuji (D-12)	0.006	0.06	0.18	1.8	<0.001	<0.01	0.001	<0.01	0.18	1.8
Iwakuni MCAS (D-13)	0.001	0.01	0.026	0.26	<0.001	<0.01	<0.001	<0.01	0.027	0.27
Sasebo NB (D-14)	0.001	0.01	0.033	0.33	<0.001	<0.01	<0.001	<0.01	0.034	0.34

[*] Doses were calculated based on conservative assumptions resulting in PEP doses that were greater than the 95th percentile values from the probabilistic dose analysis (Cassata et al., 2012; Chehata et al., 2013).

[†] These PEP doses were calculated assuming no time indoors and extremely high physical activity levels.

[‡] Dose contributions from air inhalation at these sites were calculated using Yokota AB air concentration data.

Table 29. Internal monitoring summary for fleet and air crews

Ship	Work Location	Number of People Monitored	Number of Doses > 0	Maximum Doses (mSv)		Average Doses (mSv)	
				Effective	Thyroid	Effective	Thyroid
USS George Washington (CVN 73)	CCSG 5	1	1	0.08	1.34	0.08	1.34
	COM CVW 5	1	0				
	CVN 73	533	26	0.06	0.90	0.03	0.46
	HS 14	213	1	0.03	0.44	0.03	0.44
	VAQ 136	2	0				
	VAW 115	22	0				
	VFA 102	9	0				
	VFA 115	9	0				
	VFA 195	7	0				
	VFA 27	6	1	0.04	0.60	0.04	0.60
	VRC 30 DET 5	49	0				
	Ship Total	852	29	0.08	1.34		
USS Ronald Reagan (CVN 76)	CCSG 7	1	0				
	COM CVW 14	3	0				
	CVN 76	664	30	0.25	4.03	0.04	0.61
	HS 4	115	1	0.03	0.49	0.03	0.49
	VAQ 139	134	7	0.03	0.56	0.03	0.48
	VAW 113	109	1	0.03	0.53	0.03	0.53
	VFA 146	100	4	0.03	0.52	0.03	0.47
	VFA 147	112	0				
	VFA 154	122	0				
	Ship Total	1360	43	0.25	4.03		

Table 29. Internal monitoring summary for fleet and air crews (cont.)

Ship	Work Location	Number of People Monitored	Number of Doses > 0	Maximum Doses (mSv)		Average Doses (mSv)	
				Effective	Thyroid	Effective	Thyroid
USS Blue Ridge (LCC 19)	LCC 19	100	0				
	COMDESRON 15	40	0				
	COMSEVENTHFLT	36	0				
	Ship Total	176	0				
USS Chancellorsville (CG 62)	CG 62	29	0				
USS Cowpens (CG 63)	CG 63	168	0				
USS Shiloh (CG 67)	CG 67	42	0				
USS Curtis Wilbur (DDG 54)	DDG 54	33	0				
USS John S. McCain (DDG 56)	DDG 56	32	0				
USS Fitzgerald (DDG 62)	DDG 62	228	0				
USS Stethem (DDG63)	DDG 63	29	0				
USS Lassen (DDG 82)	DDG 82	37	0				
USS McCampbell (DDG 85)	DDG 85	33	0				
USS Preble (DDG 88)	DDG 88	24	0				
USS Mustin (DDG 89)	DDG 89	33	0				
USS Essex (LHD 2)	LHD 2	731	1	0.03	0.42	0.03	0.42
USS Germantown (LSD 42)	LSD 42	5	0				
USS Tortuga (LSD 46)	LSD 46	175	1	0.02	0.40	0.02	0.40
USS Harpers Ferry (LSD 49)	LSD 49	26	0				
	All Ships	4013	74	0.25	4.03		
HSL 51 LAMPS (Assigned to Misawa AB)	HSL 51 LAMPS	174	2			0.11	1.84
	Total	4187	76	0.25	4.03		

The average effective dose was 0.03 mSv (0.003 rem) and the average thyroid dose was 0.57 mSv (0.057 rem) for doses greater than zero.
- No IM results are available for seven USNS ships (Richard E Byrd, Carl Brashear, Matthew Perry, Pecos, Rappahannock, Bridge, and Safeguard).

The greater percentage of fleet and air crew internally monitored as compared to shore-based personnel (25 versus 8) is probably due to two things. First, the personnel onboard a ship were more readily available for IM because they were generally confined to a ship. The personnel doing the monitoring on the ships reported that they were opportunistically monitoring anyone they could and tried to get as many people monitored as possible. Second, the fleet and air crews were more directly involved in humanitarian work and were more likely be associated with contamination and therefore were preferentially sought for internal monitoring.

The aircraft carrier personnel assigned to the USS George Washington (CVN 73) and the USS Ronald Reagan (CVN 76) showed roughly the same statistics. The number of CVN 73 personnel monitored was 533 compared with 664 for CVN 76 and the greater-than-zero doses for CVN 73 were 26 (4.7%) compared with 30 (4.5%) for CVN 76. The maximum effective and thyroid doses for CVN 76 were about four times higher than for CVN 73. However, this represents only a single person with the maximum doses. For those personnel with greater-than-zero doses, the average effective dose for CVN 76 was 0.04 mSv compared with 0.03 mSv for CVN 73, which are nearly identical, and both are very small and of no health consequence.

The internal monitoring environment onboard ships was ideal because of the low background rates due to low terrestrial radiation and the greater shielding offered by the structure of the ship. Background rates on ships measured about 10 times lower than rates at the shore-based sites at Atsugi NAF, Yokosuka AB, and Okinawa.

8.2.3. Relationship of IM Doses with Dosimeter Measurements

Personnel dosimeters were issued to individuals who were determined to have a potential for exposure to external radiation in performing their duties, such as assistance in humanitarian relief, entrance into the warm or hot zones, or as a routine requirement of their duties (occupations). The latter groups included nuclear trained individuals and medical individuals working with radiation sources. External personnel monitoring was performed using three unique technologies: the USAF and USN electronic personal dosimeter (EPD), the USAF and USN thermoluminescent dosimeter (TLD), and the USA optically stimulated luminescent (OSL) dosimeter. The USA, USN, and USAF all have large, well-established, nationally accredited dosimetry centers in CONUS. Each of the services provided methods for distribution and collection. Appendix H is an example of the Navy's guidance for documenting the distribution of personal thermoluminescent dosimeters for OT activities.

Records for 3,677 OT personal dosimeters have been identified and assigned to unique individuals. The number of unique individuals is lower than the number of dosimeters because some individuals have multiple dosimeter records. The results of current assessments are presented in Table 30.

Table 30. OT individual dosimeter statistics

Service	Number of Dosimeter Records	Number of Dosimeters per Dose Category (mrem)					
		0	1-25	26-50	51-100	101-500	>501
U.S. Army	334	282	50	0	1[†]	1[†]	0
U.S. Navy	1,870	1560	310	0	0	0	0
U.S. Air Force[*]	1,395	699	695	1	0	0	0
DTRA	27	21	6	0	0	0	0
Total	3,626	2,562	1,061	1	1	1	0

[*] Table entries represent dosimeters issued and processed and include those issued to members of other military services.

[†] At the time this report was written this result was under investigation.

Direct comparison of IM results with dosimeter results was not possible because IM results are internal doses and personal dosimeters indicate external doses. However, it is informative to identify associations between these results. For example, 53 applicable dosimeter records for ship-based and fleet air unit individuals were identified and were compared to available IM results. There were six non-zero dosimeter results in this set of 53, involving personnel assigned to USS Blue Ridge, USS George Washington, and USS Essex. Four of these results are in the range 1–25 mrem, and two are in the range 26–50 mrem. IM results for all 53 individuals are less than MDA. Therefore, the majority (47) of the available dosimeter results are consistent with the IM results of "less than MDA".

Based on the mix of radionuclides in FDNPS airborne releases, the fractions of individuals with results of "zero" from personal dosimeters and from IM measurements can generally be expected to be reasonably comparable. Furthermore, the magnitudes of doses from IM and from personal dosimeters are both consistent, and lead to the conclusion that they are well below a level of concern for health effects associated with exposure to radiation. The task of correlating IM measurements with dosimeter results is ongoing and will be reported in an appropriate manner when available.

8.2.4. Time after Intake Considerations

Intake activities are calculated from measured internal activities with an IRF as shown by Equation 21.

$$A_{I,i} = \frac{A_{M,i}}{IRF_i} \tag{21}$$

where:

$A_{I,i}$ = Calculated intake activity for radionuclide *i* (Ci or Bq)

$A_{M,i}$ = Measured activity for radionuclide *i* (Ci or Bq)

IRF_i = Intake retention fraction for radionuclide *i* (unitless)

The intake activity was always larger than the measured activity because of radioactive decay and biological elimination as shown in Figure 16 and Figure 17 above. Thus, the IRF values are always less than 1.0 and decrease with time after intake. The following example illustrates the time dependence between the measured activity and the intake activity. A measurement of 1 nCi of I-131 on the thyroid at 30 days after intake yielded an intake activity of 115 nCi, whereas a measurement of 1 nCi of I-131 on the thyroid 40 days after intake yielded an intake activity of 290 nCi.

The value at which a decision can be made that a positive quantity of a radioisotope is present is the critical activity level. However, at this level Figure 15 shows that there is a 2.5% chance of making a type I or a type II error. Therefore, in the OT RIMIS system the MDA was used to discriminate when a measurement was truly above background in order to minimize the number of false positives (type II error), i.e., falsely assuming that a measured activity was due to an intake of an radionuclide when it wasn't. As shown by Equation 3, MDA is a function of the background count rate and the coefficient of variation in the measurement system.

Doses were entered as zero when both the thyroid and whole body IM measurements were less than the MDA. For results less than the MDA for the DOD-affiliated individuals involved in OT operations, the individual's actual dose is most likely at or near zero because the environmental concentrations of material released from FDNPS were low at the locations where most of the DOD-affiliated individuals were located for most time periods. This conclusion is supported by the fact that results for more than 97 percent of OT RIMIS measurements are less than the MDA values. But it is possible that an intake resulted in a true activity on the measurement date ranging from zero up to just below the MDA (i.e., an intake of radioactivity that resulted in uptake measurement below the detection limit of the measurement system or which was partially eliminated through radioactive decay or bioelimination below the detection limit). Thus, it was useful to determine potential intake activities that corresponded to the system's MDA to bound the upper potential intake activity.

The information discussed above was used to help characterize a zero dose result in discussions with the individual. For example, for an individual with a zero dose (a result less than the MDA), two conclusions were made:

- Their IM result showed that no activity was measured above the MDA on the date of the IM measurement, and
- Any internal effective dose resulting from an actual (but undetected) intake was no higher than what would be calculated by assuming the measured activity was just below the MDA, together with an assumed earliest possible date of intake.

Any contemporary explanations of results below the MDA should be used in conjunction with other information such as the available environmental measurements, and the results of dose calculations of potential doses for other individuals with similar exposure situations. Cassata et al., (2012) reported conservative doses calculated from daily environmental measurements for 13 shore-based locations where DOD-affiliated individuals were located. None of the IM total calculated doses for shore-based individuals should be in conflict with doses calculated in Cassata et al. (2012).

Any explanations of results below MDA should not go beyond these general statements and comparisons without also including more specific information regarding the individual. For

example, if the individual's intake date can be estimated more accurately than what is conservatively used in the IADCT calculations, the estimated intake activity can be modified. The earliest possible date of potential intake is used in IADCT, but if it can be established that an individual was potentially exposed to FDNPS released material on a later date than what is used in IADCT, a lower estimated intake (and associated dose) would be calculated than if the earlier date is assumed. Additionally, location specific doses calculated from environmental measurements, as was done in Cassata et al. (2012) should be used in conjunction with IM results.

Figure 31 shows the qualitative relationships between measured cpm, MDA[4] and time after intake for IM measurements made with portable systems. For this illustration it was assumed that an intake occurred consisting of 5 days of breathing air at the same activity concentrations as measured by the YR-95 barge at Yokosuka NB on March 15, 2011. In this figure I-131 could be detected for about 37 days after intake in a 6,000 cpm background and could be detected until 45 days after intake in a 3,000 cpm background. Cs-134/Cs-137 could be detected until approximately 145 days after intake in a 6,000 cpm background and could be detected until 245 days after intake in a 3,000 cpm background. The largest number of days after intake for OT RIMIS operations was less than 170 days and the average background count rate was less than 3,000 cpm.

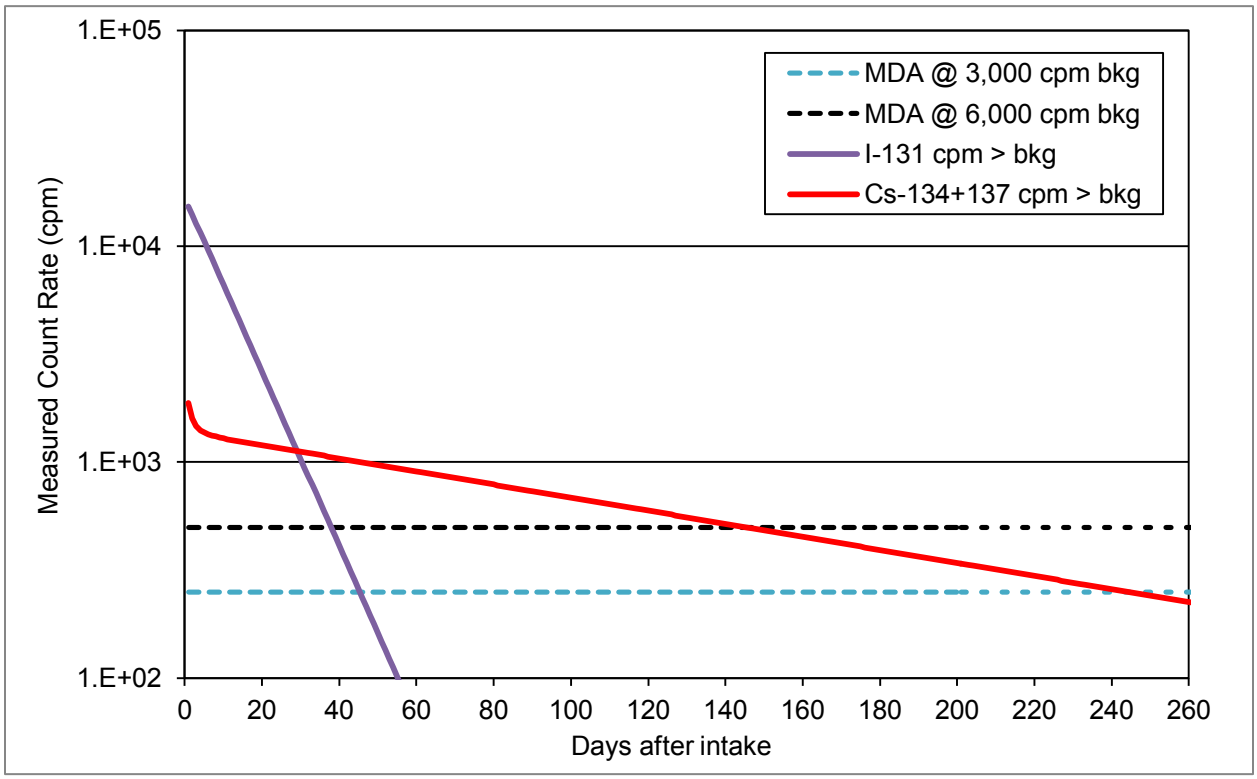

Figure 31. Qualitative relationships between measured cpm, MDA, and time after intake.

[4] For the purposes of Figure 31, MDA is expressed as cpm of a single radionuclide.

Section 9.

Conclusions

The OT RIMIS program was designed, staffed, and implemented with strong technical oversight in compliance with USPACOM policy and procedures to achieve the program's objectives presented in Section 1.2. The program incorporated rigorous quality assurance measures throughout its design, development and implementation phases.

During the program, 8,378 IM measurements were performed successfully on 7,947 DOD-affiliated individuals from March 16 through August 31, 2011. About 3 percent of those measurements had an activity greater than the MDA. The activities that were greater than the MDA resulted in a maximum committed effective dose of 0.25 mSv (0.025 rem) and a maximum committed equivalent dose to the thyroid of 4.2 mSv (0.42 rem). These results demonstrate internal radiation doses of the 70,000 DOD-affiliated individuals of concern were low and would not require any medical intervention under U.S. radiological protection guidance.

The approach, methods, and technical basis for the reported IM doses were reviewed by nationally recognized experts serving on Scientific Committee 6-8 of the NCRP. These reviewers provided invaluable technical contributions that were incorporated into the methodology and into this report. The DARWG appreciates the NCRP committee's comments and believes both the technical approach used for calculating IM doses and this resulting technical report have been substantially improved because of the review provided.

9.1 Program Objectives

The USPACOM Surgeon implemented the OT RIMIS program to assess DOD-affiliated individuals' intakes of radioactive materials released from the FDNPS. The four program objectives (see Section 1.2), conceived early in the development phase, were essential to its success.

9.1.1. Individual Assessment

The OT RIMIS program successfully provided 8,378 individual internal monitoring measurements on 7,947 DOD-affiliated individuals during the 169-day period from March 16 through August 31, 2011. The IM process provided timely evaluations to individuals using a priority system that was based on the likelihood of internal exposure. Over 75 percent of the measurements were completed by the end of May 2011, which was about two months after passing of the major contaminated plumes.

As stated in Section 6, understandable, qualitative information about the measurement and its medical significance was provided to individuals immediately upon completion of their IM measurement using a three-tiered reporting dialogue written with the help of USPACOM risk communicators.

The OT RIMIS program made important contributions by informing DOD-affiliated individuals about their levels of internal radiation exposure during ongoing operations, which allowed them to confidently continue and complete their missions. Further, the calculated

internal doses affected few individuals (about 3 percent with measureable doses) and were small in magnitude [the mean committed effective and thyroid committed equivalent doses for those activities greater than the MDA during the OCONUS operational period were 0.06 mSv (0.006 mrem) and 1.0 mSv (0.10 mrem), respectively].

9.1.2. Reports to Operational Commanders

Operational commanders were provided daily summaries of measured internal doses at a time when situations were changing rapidly and the communication of highly technical information presented challenges. They were reassured throughout the mission that the people under their command were not receiving significant internal contamination. This reinforced expectations that the implemented radiological controls and operational procedures were sufficiently protective for the operational environments and for the missions being performed.

In addition, timely feedback proved essential to operational commanders' confidence that the issued directives were being followed. The operational control limit imposed by the Headquarters of the USPACOM Joint Operations Center was 300 mrem total effective dose equivalent, above which individuals were required to have external and internal monitoring and exposure recorded (USPACOM, 2011). Since the total effective dose equivalent is the sum of the external dose and internal effective dose, the OT RIMIS measurements played a critical part in assessing whether individuals exceeded the 300 mrem control limit.

Operational commanders were also given modeling results of predicted radioactive air activity concentrations that they used to plan operations to ensure that their personnel would not exceed the 300 mrem control limit. The OT RIMIS measurements were used to provide reassurance that predictions of air concentrations were reasonably representative of exposure conditions.

In summary, IM results were reported to operational commanders in a timely manner that ensured their use to provide an early assessment of internal exposures to individuals, the effectiveness of the radiological controls implemented, and to confirm predictive environmental modeling results.

9.1.3. Future Dose Investigations and Estimates

Individual dose assessments are usually unnecessary when conservative population dose estimates are small, as they were for the dose estimates in OT reported in Cassata et al. (2012). However, there may be some individuals for whom a future individual dose assessment may be necessary.

A full assessment of an individual's radiation dose requires an evaluation of both external and internal sources of dose. IM results are an integral part of such an assessment. IM results are being recorded in the OT Registry (http://registry.csd.disa.mil/otr) and will be available for future use. This report serves as the technical basis for these IM results. Together, these will be useful for evaluating the internal radiation dose component in future individualized assessments.

The objective of having reliable, technically defensible, and readily available internal doses for future individual dose investigations and estimates was successfully accomplished. The internal monitoring doses from the OT RIMIS program used internationally accepted models for the behavior of radionuclides in the body, high quality and well calibrated instrumentation, highly trained operators, and a comprehensive quality assurance plan.

9.1.4. Quality Assurance and Control

IM scans were based on comprehensive policies, procedures, and guidelines that considered quality assurance and control as an integral component of the overall management and execution effort. The OT RIMIS program benefitted from the following:

- The development of the algorithm and IADCT allowed for the calculation of an effective dose and committed equivalent dose immediately following an IM measurement.
- Any anomalous results could be immediately identified and corrected including the entry of incorrect dates, count data, or background measurements.
- The implementation of radiological controls ensured that low levels of contamination on the clothing or from the surrounding environment did not interfere with or confound IM results.
- Daily quality assurance checks on equipment by highly-trained individuals ensured that it was operating properly and providing reliable count data.
- Assignment of individual IM SMs was a key element in the quality assurance of the program. Individual SMs ensured that individuals performing the work were adequately trained and competent.
- Interactions between SMs and oversight offices ensured accurate reporting, timely two-way feedback, and rapid identification of issues requiring action.
- Daily technical review and oversight from a central USPACOM authority were performed to ensure that operations were consistent among teams and that no problems were occurring.

The design and implementation of appropriate quality assurance and control was successful and resulted in a robust and reliable program. This effort ensured that the calculated doses were accurate and scientifically valid.

9.2 Application of Radiological Emergency Response Principles

All environmental radiological releases are potential health concerns. Each radiological source must be evaluated fully until there is evidence to suggest that one source or another is not presenting a significant exposure. The probability and magnitude of exposure depend on, among other things: the number, quantity and radiological characteristics of the releases; the meteorological conditions during and after the releases and weathering effects on the releases; the locations of individuals relative to the sources of release, plume directions, and the amount of deposited fallout; the nature and physical properties of the radioactive material; the type of work or other activities individuals are performing, the kinds of contaminated objects to which individuals may be exposed, and the durations of exposure.

Radiological measurements are necessary to inform people about possible concerns from their exposure to radiation. Measurements provide the basis of any radiation safety program. Ideally, when levels of radioactivity could potentially rise to a level of concern, measurements should be taken before, during, and after an incident for as long as necessary to assure people that they are safe.

Measurement methods and plans should be well thought out and designed to meet specific objectives, performed using written procedures, and supported by technical basis

documents. The instruments used to take the measurements should be properly calibrated, traceable to national standards, and capable of meeting the measurement objectives. The instruments should be used by trained and experienced individuals, with written and standardized procedures, and results should be properly recorded and carefully reviewed each day.

For radiation surveillance for wide area releases, as was the case during OT, it was necessary to take into consideration environmental measurements such as those discussed in Cassata et al. (2012), individual external monitoring using dosimeters, and individual internal monitoring measurements. It was also necessary to conduct radiation surveys of equipment and objects to identify those that were contaminated, and if necessary the degree to which they were contaminated. The results of these measures made it possible to decide on radiation controls.

Environmental measurements at locations where DOD-affiliated individuals were working or living were used to calculate possible external and internal radiation exposures to populations living or working in those areas. This required using the results of measurements in the dose calculations, which also required: informed, conservative assumptions (about the time spent indoors/outdoors, inhalation and ingestion rates, time of intake, etc.), additional measurements or assumptions about the properties of the released radiation sources (such as, particle size distributions, percentages of isotopes present, fractions of aerosols and gaseous forms, etc.) and various parameters obtained from the scientific literature (such as intake retention factors, dose coefficients, emission fractions and energies of emitted photons or particles, etc.). Details of these calculations can be found in Cassata et al. (2012).

A dosimeter monitoring program was implemented during OT to measure the external radiation exposure to individuals directly with active and passive dosimeters. The OT RIMIS was implemented to assess the intake of radionuclides to calculate the internal dose to individuals. All the measurements discussed above were taken during OT and they provided assurance that individuals working or living in affected areas were being adequately protected against external and internal exposure to the radiation released into the environment from the FDNPS.

Section 10.

References

Bronson, F.L., Booth, L.F., Richards, D.C., (n.d.). "A Computerized, Anthropometrically Designed, High Throughput, Whole Body Counter for the Nuclear Industry," Radiation Management Corporation/Canberra Industries, Inc., Northbrook, IL. Accessed at http://www.canberra.com/literature/invivo_counting/tech_papers/fastscan.pdf on October 10, 2012.

Canberra, 2002a. "Model 2280 ACCUSCAN II™ Scanning Germanium Whole Body Counter," Product Description and Technical Specifications Sheet, Canberra Industries, Inc., August.

Canberra, 2002b. "Model 2250 FASTSCAN™ High-Throughput Whole Body Counter," Product Description and Technical Specifications Sheet, Canberra Industries, Inc., June.

Cassata, J., Falo, G., Rademacher, S., Alleman, L., Rosser, C., Dunavant, J., Case, D., Blake, P., 2012. *Radiation Dose Assessments for Shore-Based Individuals in Operation Tomodachi, Revision 1*. DTRA-TR-12-001(R1), Defense Threat Reduction Agency, Fort Belvoir, VA. December.

Chehata, M., Dunavant, J., Mason, C., McKenzie-Carter, M., Singer, H. 2013. *Probabilistic Analysis of Radiation Doses for Shore-Based Individuals in Operation Tomodachi*. DTRA-TR-12-002, Defense Threat Reduction Agency, Fort Belvoir, VA. May

CTBTO (Comprehensive Test Ban Treaty Organization), 2011. *IMS RN38 Station Status as of April 23*. Vienna. (http://www.ctbto.org) April 23.

Eckerman, K.F., Westfall, R.J., Ryman, J.C., Cristy, M., 1993. *Nuclear Decay Data Files of the Dosimetry Research Group*. ORNL/TM-12350, Oak Ridge National Laboratory, Oak Ridge, TN. December.

Eckerman, K.F. and Sjoreen, A.L., 2003. *Radiological Toolbox User's Manual*. ORNL/TM-2004/27, Oak Ridge National Laboratory, Oak Ridge, TN. December.

Fell, T. P. and Adams, N., 1978. *The effects of recycling between blood and body organs on the retention and excretion of radionuclides by the body*. Harwell, NRPB, Annual Research and Development Report NRPB-R&D3, UK National Radiological Protection Board, Chilton.

GOJ (Government of Japan), 2011a. *Report of the Japanese Government to the IAEA Ministerial Conference on Nuclear Safety, The Accident at TEPCO's Fukushima Nuclear Power Stations*, Nuclear Emergency Response Headquarters, Government of Japan. June.

GOJ (Government of Japan), 2011b. *The Accident at TEPCO's Fukushima Nuclear Power Stations (Second Report)*. Nuclear Emergency Response Headquarters, Government of Japan. September.

HPS (Health Physics Society), 2010. *Radiation Risk in Perspective*, Position Statement of the Health Physics Society. July. (http://hps.org/documents/risk_ps010-2.pdf, accessed September 1, 2012)

ICRP (International Commission on Radiological Protection), 1979. *Limits for Intakes of Radionuclides by Workers*. ICRP Publication 30 (Part 1). Ann. ICRP 2 (3-4).

ICRP (International Commission on Radiological Protection), 1980. *Limits for Intakes of Radionuclides by Workers*. ICRP Publication 30 (Part 2). Ann. ICRP 4 (3-4).

ICRP (International Commission on Radiological Protection), 1988. *Radiation Dose to Patients from Radiopharmaceuticals*. ICRP Publication 53. Ann. ICRP 18 (1-4).

ICRP (International Commission on Radiological Protection), 1990. *Age-dependent Doses to Members of the Public from Intake of Radionuclides - Part 1*. ICRP Publication 56. Ann. ICRP 20 (2).

ICRP (International Commission on Radiological Protection), 1991. *1990 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 60 Annals of the ICRP, 2*1*(1–3), Pergamon Press., Oxford, UK.

ICRP (International Commission on Radiological Protection), 1994a. *Human Respiratory Tract Model for Radiological Protection*, ICRP Publication 66. *Annals of the ICRP 24 (1-3)*, Elsevier Ltd., Oxford, UK.

ICRP (International Commission on Radiological Protection), 1994b. *Dose Coefficients for Intakes of Radionuclides by Workers*, ICRP Publication 68. *Annals of the ICRP 24 (4)*, Elsevier Ltd., Oxford, UK.

ICRP (International Commission on Radiological Protection), 1995. *Age-dependent Doses to Members of the Public from Intake of Radionuclides - Part 4 Inhalation Dose Coefficients,* ICRP Publication 71. *Annals of the ICRP*, 25(3–4), Elsevier Ltd., Oxford, UK.

ICRP (International Commission on Radiological Protection), 1997. *Individual Monitoring for Internal Exposure of Workers*, ICRP Publication 78. Annals of the ICRP, 27 (3-4), Elsevier Ltd., Oxford, UK.

ICRP (International Commission on Radiological Protection), 2001. *ICRP Database of Dose Coefficients: Workers and Members of the Public, Version 2.0.1, 1998-2001*. International Commission on Radiological Protection, Stockholm, Sweden.

ICRP (International Commission on Radiological Protection), 2003. *ICRP CD2: Database of Dose Coefficients: Embryo and Fetus, Version 1.0*, International Commission on Radiological Protection, Stockholm, Sweden.

ICRP (International Commission on Radiological Protection), 2007a. *The 2007 Recommendations of the International Commission on Radiological Protection*. ICRP Publication 103. Annals of the ICRP, 37 (2-4), Elsevier Ltd.

ICRP (International Commission on Radiological Protection), 2007b. *ICRP CD 3: Database of Dose Coefficients: Radionuclides in Mothers' Milk, Version 1.0*, International Commission on Radiological Protection, Stockholm, Sweden.

ICRP (International Commission on Radiological Protection), 2012. *Compendium of Dose Coefficients based on ICRP Publication 60*. ICRP Publication 119. Annals of the ICRP 41(Suppl.), Elsevier Ltd.

Johnson, M.L., 2009. *Radiation Protection Instrument Manual PNL-MA-562*. Pacific Northwest National Laboratory, Hanford, Washington, August.

Musolino, S.V., Clark, H., McCullough, T., and Pemberton, W., 2012. "Environmental Measurements in an Emergency: This is not a Drill." *Health Physics,* 102(5): 516–526.

NCRP (National Council on Radiation Protection and Measurements), 2009. *Ionizing Radiation Exposure of the Population of the United States*. NCRP Report No. 160, National Council on Radiation Protection and Measurements, Bethesda, MD. March 3.

NCRP (National Council on Radiation Protection and Measurements), 2010. *Population Monitoring and Radionuclide Decorporation Following a Radiological or Nuclear Incident*. NCRP Report No. 166, National Council on Radiation Protection and Measurements, Bethesda, MD.

Potter, C.A., 2002. "Intake Retention Fractions Developed from Models Used in the Determination of Dose Coefficients Developed for ICRP Publication 68—Particulate Inhalation," *Health Physics*, 83 (5): 594–789.

PSNS (Puget Sound Naval Shipyard), 2011. *Internal Monitoring Procedures using ABACOS Software*. Internal Monitoring Guideline, Number 10, Change 4, Puget Sound Naval Shipyard and Intermediate Maintenance Facility, Naval Base Kitsap, Bremerton, WA. January 25.

PSNS (Puget Sound Naval Shipyard), 2012a. *Internal Monitoring using the ACCUSCAN-II with ABACOS-2000*. Internal Monitoring Guideline, Number 6, Change 3, Puget Sound Naval Shipyard and Intermediate Maintenance Facility, Naval Base Kitsap, Bremerton, WA. March 14.

PSNS (Puget Sound Naval Shipyard), 2012b. *Monitoring Instructions Using the PSNS Accuscan II*. Puget Sound Naval Shipyard and Intermediate Maintenance Facility, Naval Base Kitsap, Bremerton, WA. Undated.

PSNS (Puget Sound Naval Shipyard), 2012c. *Monitoring Instructions Using the STANDFAST or FASTSCAN*. Puget Sound Naval Shipyard and Intermediate Maintenance Facility, Naval Base Kitsap, Bremerton, WA. Undated.

PSNS (Puget Sound Naval Shipyard), 2013. Email, dated April 16, 2013, from Richard G. Siler, Puget Sound Naval Shipyard and Intermediate Maintenance Facility to James Cassata.

Selwyn, R., 2011. "E600/SSPA3 Iodine-131 Calibration,"*[sic]* Memorandum to File, Uniform University of the Health Sciences, Bethesda, MD, April 10.

Thermo Electron, 2004. "E-600 Multipurpose Survey Meter," Product Specifications Sheet, Thermo Electron Corporation, Santa Fe, NM.

USPACOM (United States Pacific Command), 2011. USPACOM Message, DTG:161643Z Mar 11, Subject: CDRUSPACOM Guidance On Radiation Force Health Protection Requirements For U.S. Forces Supporting Operation Tomodachi, March 16.

Zanzonico, P.B., 2000. "Age-dependent Thyroid Absorbed Doses for Radiobiologically Significant Radioisotopes of Iodine" *Health Physics*, 78 (1): 60–67.

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Appendix A.

Concept of Operations

This appendix contains the initial and final versions of the "Concept of Operations for Internal Monitoring of DOD Personnel Participating in Operation Tomodachi." These documents describe the roles, responsibilities and procedures for all DOD-affiliated individuals and facilities that were involved with the OT RIMIS. Items addressed include: equipment; monitoring phases; roles and responsibilities of U.S. Navy facilities, personnel, and commands; Radiation Safety Personnel responsibilities; and monitoring procedures to be followed. The initial version is included at A-1. The updated version (A-2) revises sections and appends the roles, responsibilities, and procedures presented in the initial version.

A-1. Initial Version (Apr 8, 2011)

The following pages contain the text of the document entitled "Concept of Operations for Internal Monitoring of Department of Defense Personnel Participating in OPERATION TOMODACHI," dated April 8, 2011.

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Concept of Operations for Internal Monitoring of Department of Defense Personnel Participating in OPERATION TOMODACHI (8 Apr 2011)

1. Purpose. This document outlines roles, responsibilities and procedures for persons and facilities involved with internal monitoring of DoD personnel for internal radionuclide deposition as a result of participating in OPERATION TOMODACHI.

2. Background. The 11 March 2011 earthquake and tsunami that caused extensive damage in eastern Japan also damaged facilities at the Fukushima Daiichi nuclear power plants, leading to a release of significant quantities of radioactive material into the atmosphere. U.S. forces participating in humanitarian assistance missions associated with this event have likely been exposed to the released radioactive material. Internal monitoring of Navy personnel returning from the Yokosuka, Japan area, who were exposed to airborne radioactivity when the plume passed over Yokosuka, identified very low levels of internally deposited radioactivity. For reactor accidents, uptake of I-131 in the thyroid and Cs-137 in the lungs are of primary concern for determining organ and whole body doses. Accordingly, it is appropriate to expand the Navy's existing internal monitoring process to determine the extent of potential internal contamination among DoD personnel assigned in Japan who had elevated risk of exposure, and estimate the doses for personnel with positive results. This limited plan proposes to obtain an initial population sampling of internal monitoring results to assist U.S. Pacific Command (USPACOM) in determining whether wider scale internal monitoring is necessary or desirable.

3. Scope. This directive applies to U. S. Active Duty military and DoD civilian personnel (by exception) that operated in the OPERATION TOMODACHI AOR, and Naval activities in the AOR that provide internal monitoring.

4. Overview.

a. Human radiation dose is based on two component sources. The first exposure component is external dose. External dose can be accurately measured using personnel dosimeters or estimated using instruments that measure ambient radiation levels. The second component depends on dose to specific organs and the whole body resulting from radioactivity taken into the body. This component is determined by measuring internal radioactivity and cannot be effectively determined using personnel dosimeters and direct radiation survey instruments.

b. Sophisticated assets for conducting non-invasive internal monitoring in the OPERATION TOMODACHI AOR are extremely limited. Counting large numbers of personnel using the whole body counter currently in theatre would be time consuming and unnecessary for a large part of the population that acquired little or no (i.e. less than detectable) radioisotope uptake. Therefore, sampling is appropriate to identify populations that warrant further monitoring.

c. Non-invasive internal counting can be provided for large scale sampling (e.g. up to a few thousand people) using field instruments that are properly calibrated and

programmed for acquiring information from inhaled and ingested radionuclides of interest (i.e. I-131 and Cs-137).

d. Field data collection will be performed using Thermo Model E600/SPA3 portable detector systems calibrated for this purpose by the Knolls Atomic Power Laboratory (KAPL). Monitoring will also be performed using either a Canberra Accuscan or a Canberra Fastscan (upon arrival) whole body counter.

i. The sampling scheme assumes that large numbers of personnel in the AOR were potentially exposed to airborne radioactivity from the damaged reactors. Due to the timeliness necessary to acquire the data, (i.e. effects of radioactive decay), it is necessary to characterize the affected population in broad, qualitative terms suggested by recent verified contamination events.

ii. Monitoring shall occur in three phases.

1. Phase 1 will concentrate on Active Duty personnel from all Services operating within the Sendai area.

2. Phase 2 will include helicopter crews from all Services that have flown missions through known plumes.

3. Phase 3 will include support personnel (including individuals who decontaminated affected aircraft, ships and support equipment ashore). This phase also includes sea and shore based personnel supporting the Naval Nuclear Propulsion Program (NNPP).

4. Phase 2 and 3 monitoring may occur simultaneously based on the availability of personnel identified to be monitored, monitoring equipment and local radiological conditions.

iii. During the initial stages of Phase 1, personnel stationed in the Sendai area shall be monitored using both the Accuscan and E600/SPA3 systems to determine cross correlation efficacy between the two instruments and suitability for the E600/SPA3 instruments to be used singularly for field work by USPACOM.

1. Per NCRP Report 55, the absolute individual risk for thyroid cancer for adults and children is 6×10^{-6}/rem/yr and the threshold for hypothyroidism in adults and children is approximately 20 rads.

iv. Upon determination by USPACOM that the E600/SPA3 system is fit for independent operation, personnel in Phase 2 and 3 shall be monitored using E600/SPA3 systems according to the schedule provided in Table 1. A number of personnel from these groups with uptakes above and below MDA shall also be

monitored using one of the Canberra systems to obtain more precise measurements and maintain cross correlation efficacy between the two instrument sets.

1. Active duty and civilian personnel supporting the NNPP shall be identified and monitored as prescribed by NAVSEA in Phase 3.

2. All evaluated personnel shall be monitored for I-131 deposition in the thyroid gland and Cs-137 in the lungs.

3. Personnel may be monitored using a Canberra system directly if a E600/SPA3 system is not readily available at the desired monitoring time or if environmental conditions preclude effective use of the portable unit (e.g. high background radioactivity levels).

e. Health physics personnel may estimate committed dose equivalents (CDE) and committed effective dose equivalents (CEDE) for personnel with internal radioactivity that exceeds the systems' minimum detectable activities (MDA).

5. Action. This guidance is specific to the field data collection phase only.

a. Knolls Atomic Power Laboratory (KAPL). KAPL shall:

i. Develop a procedure for using Thermo E600/SPA3 units to determine deposition of I-131 and Cs-137 activity in the thyroid and lungs of tested subjects.

ii. Provide technical support for this monitoring. Answer technical questions from operations in the field and supervise activities regarding the procedure and resulting analysis.

iii. Provide assistance with the interpreting the results obtained from the Canberra and Thermo monitoring systems and the effect of multiple depositions on results.

b. Navy Bureau of Medicine and Surgery. Under USPACOM oversight, BUMED shall:

i. Recommend the minimum internalized activity detected using an E600/SPA3 portable unit that requires further monitoring using a whole body counter for Phase 2 and 3.

ii. Recommend the minimum detectable internalized thyroid and lung activity requiring conversion to CDE using the E600/SPA3 system and Canberra systems.

iii. Recommend the minimum lung and thyroid CDE and CEDE requiring further medical monitoring and advise commands on follow-on procedures for affected subjects.

iv. In coordination with NAVSEA and USPACOM PAOs, develop a strategic communications plan and associated public affairs guidance (PAG) addressing the purpose and scope of the monitoring and any potential follow-up actions that may be developed as a result of the monitoring.

v. Through the Naval Dosimetry Center, forward internal monitoring information to participating Navy commands and counterpart dosimetry activities for the other services.

vi. In coordination with USPACOM recommend the need for additional internal monitoring based on the outcome of Phase 1-3 results.

vii. Provide oversight for assignment of radiological control technicians (RCTs), radiation health officers (RHOs) and radiation health technicians (RHTs) performing functions related to internal monitoring.

c. Puget Sound Naval Shipyard and Intermediate Maintenance Facility. PSNS & IMF shall:

i. Recommend a practical Minimum Detectable Activity (MDA) for the scanning systems used in this study.

ii. Monitor identified subjects using the Canberra systems and NAVSEA approved procedures for I-131 and Cs-137 deposition in the thyroid and lung, respectively.

1. Record the information using NAVSEA approved worksheets.

2. Provide the pre-approved, brief perspective statement to subjects showing measurable uptake at the time of scanning.

iii. Train assigned Radiological Controls Technicians (RCTs), Radiation Health Officers (RHOs), and Radiation Health Technicians (RHTs) on the use of the E600/SPA3 system and KAPL internal monitoring procedure for the purpose of this sampling. Train these personnel in the appropriate handling of Personally Identifiable Information (PII) collected for purposes of internal monitoring and dose estimation.

iv. Provide field ready E600/SPA3 systems for field use aboard ships and at shore locations upon PACOM approval of standalone use suitability.

d. Assigned Radiological Controls Technicians / Radiation Health Officers and Health Physicists / Radiation Health Technicians. Assigned RCTS, RHOs/HPs and RHTs shall:

i. Ensure monitored subjects properly complete the first and second parts of the personnel monitoring data sheet for the portable systems.

ii. Monitor selected personnel at designated shore locations and aboard ships using E600/SPA3 systems and NAVSEA approved procedures.

1. Perform background measurements before the start of each internal monitoring shift prior to monitoring personnel and at a frequency deemed appropriate based on past data and experience during internal monitoring.

2. Use the ten minute cycle time to obtain thyroid and chest data.

iii. Record individual test results on an appropriately filled personnel monitoring data sheet.

1. Properly control the data sheets as Personally Identifying Information (PII).

iv. Ensure appropriate personnel are monitored at each selected ship or shore activity per the criteria listed in Table 1 using input from the visited ship/activity.

v. Utilize the pre-approved, brief perspective statement to subjects showing measurable uptake at the time of scanning.

vi. Retain, collate, prepare and ship all resulting internal monitoring records for further analysis to USPACOM, J07 for Phase 1. Phase 2 and 3 process TBD.

vii. Calculate CDEs and CEDEs, using USPACOM approved calculations only for individuals showing internalized radioactivity above MDA using E600/SPA3 and Canberra systems.

viii. Send CDE and CEDE calculation materials to USPACOM for review prior to submission to Service Dosimetry Centers for inclusion in the monitored subjects' medical records.

e. U. S. Pacific Command (USPACOM): USPACOM shall:

i. Determine the model of internal monitoring equipment, or combination thereof, to be used for field internal monitoring.

ii. Evaluate the methodology for CDE and CEDE determination, ensuring there is concurrence among Service subject matter experts for the process.

iii. Evaluate internal monitoring results (including completed data sheets, calculation spreadsheets and other supporting media) for quality control purposes prior to authorizing release of the information to the Service components for inclusion in medical records.

f. U. S. Joint Support Force – Japan (JSF-J): JSF-J shall:

i. Provide suitable temporary housing for the whole body monitoring equipment. Provide administrative personnel for support of internal monitoring. Initially, one unit will be located in Atsugi and the other in Yokosuka.

ii. Identify personnel for monitoring from across the Services based on the criteria in sections 4.d.ii.1., 4.d.ii.2., and 4.d.ii.3. (excluding the nuclear workforce).

iii. For ships, consider the following:

1. For all ships, supporting personnel cohort selections should include a distribution of personnel who performed aircraft or ship decontamination and who normally work in various locations including exterior decks, engine room, bridge, and spaces below the waterline.

2. NAVSEA 08 will provide separate guidance to JSFJ for nuclear powered ships.

iv. For shore activities, the sampling cohort should include a distribution of personnel who performed aircraft or associated equipment decontamination, and personnel who normally work in various locations at shore facilities including the interior and exterior of buildings.

v. Ensure OCC health support is available during monitoring periods.

vi. Ensure qualified personnel are available during monitoring to answer questions reference equipment or radiation exposure.

g. Commanding Officers. Commanding Officers, Commanders and Officers in Charge shall:

i. Make selected personnel available for internal monitoring.

ii. Ensure the health record custodian enters resulting internal monitoring information in the individual's health record per NAVMED P-5055 or as determined by appropriate service directives.

h. Individuals. Individuals identified as internal monitoring subjects shall:

i. Properly complete Parts 1 and 2 of the personnel monitoring data sheet and provide any relevant amplifying information at the time of monitoring.

6. Monitoring Procedure.

a. For Phase 1 involving personnel stationed in the Sendai area, the monitoring procedure will take place as follows:

1. Personnel to be monitored will be briefed using a prepared script on the purpose of the procedure, process involved in the procedure, and the expected outcome.

2. Personnel will be monitored using both the Accuscan and E600/SPA3 systems.

3. Once monitoring is complete, the monitored subject will be provided a preliminary finding indicating the amount of radioactivity detected in his/her body and a prepared perspective statement qualifying the practical and clinical meanings of that quantity. The subject will also be told that a dose measurement based on the activity will be provided for inclusion in his or her medical record once the doses are evaluated and vetted.

4. Monitored personnel will be referred to the nearest occupational health clinic for medical follow up if the measured internal radioactivity determined using a conservative estimate for the time intake (i.e. time of arrival in theater or first plume exposure) exceeds the level that would cause the subject to receive a CEDE exceeding 500 millirem. Such activity levels may require monitoring per Service procedures but are not expected to cause any adverse health effects.

5. The completed internal monitoring data sheets shall be referred to designated health physics personnel for determination of CDE and CEDE if approved calculation is available. Otherwise the data will be entered into an electronic format (database) and the data sheets will be sent to J07, USPACOM for further analysis.

b. The monitoring procedures for the remainder of Phase1 and Phases 2 and 3 are TBD based on the outcome of lessons learned from the Sendai personnel portion of Phase 1.

7. Supporting Information.

TABLE 1. Internal Monitoring Sampling / Equipment Criteria

SAMPLING POPULATION	SAMPLING FREQUENCY	MONITORING SYSTEM E600/SPA3	Canberra
Phase 1: Active Duty personnel operating within the Sendai area	100 %	X	X
Phase 2: Aviators (i.e. helicopter pilots and aircrews) that have flown through known plumes.	100 %	X	X[1]
Phase 3: Personnel supporting aviation operations and aircraft/ship decontamination teams	100 %	X	X[1]
Phase 3:Supporting ship crew (including nuclear trained personnel)	The lesser of 100 or 10% of the crew	X	X[1]
Phase 3: Supporting shore activity personnel	The lesser of 100 or 10 % of assigned personnel	X	X[1]
Phase 3: NNPP Personnel[2]	Per NNPP requirements	X[2]	X[2]
Phase 3: Others[3]	TBD	X	X[1]

Notes:
1. Select individuals with E600/SPA3 readings above/below MDA for equipment intercomparison.
2. As deemed appropriate by NAVSEA.
3. As deemed appropriate by JSF-J, with USPACOM concurrence.

APPROVED: 

DATE: 8 APR 2011

A-2. May 17, 2011 Version

The following pages contain the text of the document entitled Concept of Operations Addendum for Internal Monitoring of Department of Defense Personnel Participating in OPERATION TOMODACHI, dated May 17, 2011.

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Concept of Operations Addendum for Internal Monitoring of Department of Defense Personnel Participating in OPERATION TOMODACHI (17 May 2011)

1. Purpose. This document updates and appends the continuing roles, responsibilities and procedures for persons and facilities involved with internal monitoring (IM) of DOD personnel for internal radionuclide deposition as a result of participating in OPERATION TOMODACHI or living on the island of Honshu following the 11 March 2011 earthquake and subsequent release of radioactivity at the Fukushima Daiichi nuclear power plant.

2. References.

a. USPACOM IM CONOPS of 8 Apr 2011

b. USF-J message 200259Z Apr 11

c. Health Risk Communication: "Internal Monitoring for Operation Tomodachi - Who, Why and What does it Mean?"

d. NAVSEA ltr 08R:JMH:jmh Ser 08R/11-01800 of 19 Apr 11

e. USPACOM Health Physicist Directive for Internal Monitoring of Personnel Participating in OPERATION TOMODACHI (latest revision)

f. Internal Monitoring Procedure for Use with the E600/SPA3 – Knolls Atomic Power Lab.

3. Background.

a. Reference (a) presented the background for the initial IM concept of operations (CONOPS). In addition to service members engaged in the relief efforts, other Americans, including DOD affiliated personnel (military members, civilians, contractors, and family members), were possibly exposed to radioactivity above normal background levels. Moreover, internal monitoring of some Navy personnel returning to CONUS from Yokosuka, Japan, who were exposed to airborne radioactivity when the plume passed over Yokosuka, identified very low levels of internally deposited radioactivity. As a result of this potential for exposure, USPACOM is expanding the existing internal monitoring process to determine the extent of internal contamination among the above named populations in Japan and estimate the doses for personnel with detectable results.

b. Per references (a) and (b), active duty personnel representing numerous geographic locations at sea and ashore, deployment periods, occupational roles and mission assignments who were expected to present a higher likelihood of internally deposited radioactivity were identified and are being internally monitored using fixed and portable internal counting systems. Since commencing IM operations, over 3600 personnel have been scanned. The internal monitoring data to date shows that

measurable quantities of radioactivity from the Fukushima Daiichi nuclear power plant were not detected for 99% of the potentially higher risk activity duty personnel. Among the 1% with positive indications of internal radioactivity, the average whole body committed effective dose equivalent (CEDE) is 16 mrem; far below levels of medical significance.

c. Although the IM data to date are consistent with the assumption that a minimal radiation dose was received by personnel, environmental sampling and modeling data indicate that some amount of radioactive material was the spread across a wide geographic area extending from the Fukushima Daiichi nuclear power plants, and the amounts decreased with distance and varied with wind direction. Surveys identified low but measurable levels of radioactive contamination on U.S. military installations in Japan.

d. To confirm minimal exposures and proactively address any concerns among the affected population, reference (a) is appended with a "final phase" to include all DOD-affiliated personnel present in or near Japan after the accidental emission of radioactive material from the Fukushima Daiichi power plant. It is imperative that an effective health risk communication message regarding internal monitoring is promulgated before the "final phase" of IM operations commence. Reference (c) has been released and should be communicated by leaders overseeing internal monitoring.

4. Scope. This directive applies to DOD affiliated personnel (military members, civilians, contractors, and family members/dependents) that were in the OPERATION TOMODACHI Area of Responsibility (AOR) between 12 March and 17 April 2011 and to DOD activities that provided IM.

5. Overview and Execution.

a. Reference (a) established monitoring into three phases of execution that corresponded to the potential risk of exposure. USFJ implemented reference (a) with the release of reference (b). Execution of initial IM CONOPS is ongoing and USFJ shall report the status of completing IM of personnel identified via ref (b) to USPACOM. PACOM shall use this information for periodic reassessment of IM operations.

b. Reference (d) directed IM of potentially affected shipboard and shore-based Naval Nuclear Propulsion Personnel (NNPP). Commands shall report the status of completing IM of personnel identified via ref (d) to USPACOM. USPACOM shall use this information for periodic reassessment of IM operations.

c. The "final phase" of IM shall provide an "open" monitoring period where DOD-affiliated personnel in Japan between 11 March and 17 April 2011, to include

military, civilians, contractors (not including foreign nationals unless they are dependents of DOD personnel), and family members/dependents, can request to be internally monitored at one of the IM sites: Yokosuka, Atsugi, Camp Zama, and Yokota.

d. Timeline.

i. 19 May 2011: Announce that IM for DOD affiliated volunteers will commence on 24 May 2011, utilizing approved health risk communication messages.
ii. 24 May 2011: Commence IM for DOD affiliated volunteers.
iii. 03 June 2011: Reassess demand for continued operations.
iv. 17 June 2011: Reassess demand for continued operations.
v. 01 July 2011: Reassess demand for continued operations.
vi. 13 July 2011: Cease all internal monitoring operations if not previously discontinued.

e. First Step - Risk Communications. As previously noted, the final phase must not start until the appropriate IM health risk communication message is promulgated (reference (c)). Base and Medical Treatment Facilities (MTF) Public Affairs Officers shall coordinate plan for release.

f. The "Final Phase" of IM can commence based on the availability of personnel to conduct monitoring and monitoring equipment engaged in current IM operations. Monitoring sites, under the oversight of their component service medical facility, are encouraged to offer IM services on an appointment basis.

i. Seven (7) IM teams shall cover three (3) fixed IM stations and four (4) portable IM stations. Portable IM stations shall be located in Yokosuka, Atsugi, Yokota and Camp Zama. Fixed IM stations shall be located in Yokosuka, Atsugi and Yokota. With the exception of Camp Zama, portable IM stations shall be set up at the corresponding fixed IM station site.

ii. JSF-J/USFJ shall report the quantity of IM volunteers daily, as USPACOM shall use this information for periodic reassessment of IM operations.

g. PACOM has determined that a practical maximum end date for internal monitoring is approximately 13 July 2011 based on the effective half-life of the predominant longest lived radionuclide (cesium) and the ability to measure a minimum CEDE about twice the current measured average assuming an intake date of 15 March.

h. USPACOM shall initially collect, processing and quality assure the IM data prior to forwarding to the Naval Dosimetry Center (NDC) for final confirmation.

Concept of Operations Addendum for Internal Monitoring of Department of Defense Personnel Participating in OPERATION TOMODACHI (17 May 2011)

USPACOM shall transfer responsibility of the collection, processing and quality assurance to the NDC on 26 May 2011.

6. Action.

a. U. S. Pacific Command (USPACOM):

i. Determine the model of IM equipment, or combination thereof, to be used for continuing and final phase internal monitoring.

ii. Evaluate the methodology for CDE and CEDE determination, ensuring there is concurrence among service subject matter experts for the process.

iii. Evaluate IM results (including completed data sheets, calculation spreadsheets and other supporting media) for quality control purposes.

iv. Develop a plan for the transfer of PACOM IM technical duties, including the initial collection of data and reporting of preliminary results. Consult with the NDC on IM quality control matters as necessary after NDC assumes responsibility for evaluating IM results.

v. Develop a strategic and risk communications plan and if required, public affairs guidance (PAG), addressing the purpose and scope of the final phase of IM and potential follow-up actions that may be necessary as result of the IM.

b. U. S. Joint Support Force – Japan (JSF-J)/U.S. Forces Japan (USFJ):

i. Per references (a) and (b), pursue IM of all higher risk individuals to the maximum extent practicable within operational limitations.

ii. Task components as appropriate to provide one (1) technician (i.e. corpsman, medic, other technician) at each IM operations site (Yokosuka, Atsugi, Camp Zama and Yokota).

iii. Maintain tactical control of IM teams. Designate single RHO to coordinate IM team operations. Provide administrative and logistics support as necessary.

iv. Report daily status of IM operations (number of volunteers completing IM) to USPACOM according to phase and/or category completion.

v. Coordinate with local medical facilities/clinics performing the final phase of IM as necessary to maximize access for DOD affiliated personnel (military members, civilians, contractors, and family members) requesting monitoring.

c. Commander U.S. 7th Fleet:

i. Afford JSF-J/USFJ tactical control over Radiation Health Officer (RHO) augmentees upon commencement of final phase operations.

d. Internal Monitoring (IM) Teams:

i. Shall be led by an RHO, who shall be designated the Internal Monitoring Site Manager (IMSM).

ii. Shall perform IM operations at designated locations.

iii. Fixed unit IM teams shall consist of an RHO, a Canberra unit technician (Puget Sound Naval Shipyard and Intermediate Maintenance Facility), and an administrator (appointed by component medical facility). Portable unit IM teams shall consist of an RHO, a technician (appointed by JSFJ/USFJ), and an administrator (shared with the fixed unit IM team).

iv. Ensure internal monitoring is carried out IAW references (a), (e) and (f). IM teams must understand and communicate the appropriate risk communication message when interacting with volunteers undergoing the final phase of IM.

v. Properly control the data sheets as Personally Identifiable Information (PII) and Protected Health Information (PHI).

e. Puget Sound Naval Shipyard and Intermediate Maintenance Facility PSNS & IMF:

i. Provide one (1) technician to oversee and support IM operations at each fixed IM site. Technician shall provide technical support, perform and record all necessary quality control checks and review the fixed unit results.

ii. Monitor identified individuals using the Canberra Fastscan and Accuscan systems and NAVSEA approved Knolls Atomic Power Laboratory (KAPL) procedures for I-131 and Cs-137 internalization.

iii. Record the information using NAVSEA approved KAPL data sheets (reference (f)).

iv. Provide the pre-approved, brief perspective statement to individuals showing any measurable uptake at the time of scanning.

v. Provide field ready E600/SPA3 systems (including battery replacement, calibration and repairs) for field use at locations designated by JSFJ/USFJ. Provide an adequate number of E600/SPA3 stands to support portable unit use.

vi. Ensure the continuous operation of three fixed IM scanners during the duration of this IM data acquisition period. Provide logistical support for fixed IM locations.

vii. Report status of IM operations completion for NNPP personnel (as outlined in reference (d)) to USF-J .

f. Knolls Atomic Power Laboratory (KAPL). KAPL shall continue to:

i. Maintain the procedure for using Thermo E600/SPA3 units to determine deposition of I-131 and Cs-137 activity in the thyroid and lungs of tested monitored individuals.

ii. Provide technical support for IM operations. Answer technical questions from operations in the field and supervise activities regarding the procedure and resulting analysis.

iii. Provide assistance with the interpreting the results obtained from the Canberra and Thermo monitoring systems and the effect of multiple depositions on results.

g. Navy Bureau of Medicine and Surgery.

i. Continue to provide the support outlined in reference (a).

ii. Manage an adequate supply of RHOs to support IM operations in Japan, as requested by JSFJ/USFJ and C7F.

iii. Support the Naval Dosimetry Center (NDC) as requested.

iv. Through Navy Medicine West, support the U.S. Naval Hospital Yokosuka as requested.

h. Naval Dosimetry Center (NDC) :

i. Assume responsibility for the technical management, initial collection of data, and reporting of preliminary results from USPACOM by 26 May 2011.

ii. Evaluate IM results (including completed data sheets, calculation spreadsheets and other supporting media) for quality control purposes prior to authorizing release of the information.

iii. Review the final technical assessment of the CEDE and CDE for all persons internally monitored.

iv. Provide final CEDE and CDE results to respective Naval activities for inclusion in active duty medical records, to Army and Air Force dosimetry centers for processing as appropriate for their personnel, and the OSD(HA) designated activity for processing of civilian and dependent doses.

v. Arrange for the technical peer review of the Internal Activity and Dose Calculation Tool Technical Basis Document by one non-governmental source.

vi. Provide a central storage location for electronic and hardcopy IM calculation spreadsheets and supporting documents associated with OPERATION TOMODACHI.

i. Component Surgeons General and subordinate Commanding Officers and/or Officers-in-Charge of Japan Medical Treatment Facilities (MTF) and/or medical clinics

i. Task respective component medical facilities (Navy (x2) – Yokosuka and Atsugi, Air Force – Yokota, Army – Camp Zama) to provide one (1) administrator/MTF liaison (i.e, corpsman, medic, medical assistant) at each IM operations site for final phase IM operations. This administrator/MTF liaison shall manage scheduling of volunteers for IM, under the oversight of the IMSM.

ii. Coordinate with Component Commanders/Commanding Officers and PSNS & IMF to find suitable locations for final phase IM operations. This need not be in a medical facility, but does require medical facility oversight of the temporary location. Consideration should be made for parking, accessibility, communications

(internet/telephone line), administration and weight-bearing for fixed units.

j. Component Commanders/Commanding Officers (Commander U.S. Naval Facilities Japan, 5th Air Force, U.S. Army Japan). Commanding Officers, Commanders and Officers in Charge shall:

i. Ensure higher-risk personnel designated in references (a) and (b) are available for IM.

ii. Per paragraph (i), assist the respective component medical facility and PSNS & IMF in establishing a suitable location for final phase IM. Fixed units have a significant weight bearing requirement.

iii. Provide widespread communication for the availability of IM for DOD affiliated personnel (military, civilians, contractors, and family members) that were possibly exposed to radioactivity above normal background levels. Command/Installation Public Affairs Officers (PAOs) should be utilized to determine the most appropriate means for announcing final phase operations.

iv. Command/Installation PAOs shall ensure USPACOM IM risk communication messages are utilized and widely disseminated prior to commencement of the final phase IM operations. PAOs shall not develop/disseminate independent risk communication guidance without the approval of USPACOM.

v. Keep chain of command aware of adverse concerns or public perception over IM operations.

7. Monitoring Procedure. Persons will be monitored, and IM results and records shall be handled, processed and retained, using the procedures specified in references (e) and (f). More specifically:

a. Persons to be monitored will be briefed using the approved, prepared script on the purpose of the procedure, process involved in the procedure, and expected outcome.

b. Persons to be monitored shall be screened to minimize the likelihood that small amounts of external radioactive contamination on their clothing or person is not misinterpreted by the IM system as internalized. Persons to be monitored will be briefed prior to arriving for monitoring on the need to wear clean clothing and footwear.

c. Persons will be monitored using either a fixed Canberra system (Accuscan or Fastscan) or portable system (E600/SPA3), depending on local site availability.

d. If the monitored person shows an uptake $\geq$ MDA using an E600/SPA3 unit, he/she shall be re-monitored using one of the fixed systems, to the extent possible by operational limitations, to obtain a confirmatory reading. Those persons monitored at Camp Zama having an uptake greater than MDA shall be referred to the Atsugi fixed unit.

e. Once monitoring is complete, the monitored person will be provided a preliminary finding using the approved, prepared perspective statement qualifying the practical and clinical meanings of activity detected. The person will also be told that a resulting dose may be provided for inclusion in the medical record once the preliminary result is verified.

f. Monitored persons will be referred to the nearest occupational health clinic for medical follow up if the measured internal radioactivity determined using a conservative estimate for the time intake exceeds the level that would cause the person to receive a CEDE that exceeds 500 mrem. Such activity levels may require monitoring per Service procedures but are not expected to be observed or to cause adverse health effects.

APPROVED:

DATE: 16 MAY 2011

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Appendix B.

Health Physics Directive (Final - July 22, 2011)

The following pages contain the text of the document entitled HEALTH PHYSICIST DIRECTIVE FOR INTERNALLY MONITORING PERSONNEL PARTICIPATING IN OPERATION TOMODACHI (REV, 22 July 2011).

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HEALTH PHYSICIST DIRECTIVE FOR INTERNALLY MONITORING PERSONNEL PARTICIPATING IN OPERATION TOMODACHI (Rev 22 July 2011)

1. References.

a. USPACOM IM CONOPS of 8 Apr 2011

b. JSFJ message 200259Z Apr 11

c. USPACOM 2XXXXXZ May 11. "Concept of Operations for Voluntary Internal Monitoring of DOD Affiliated Personnel."

d. Internal Monitoring Procedure for Use with the E600/SPA-3 – Knolls Atomic Power Lab.

e. AccuScan Procedures Document

f. FastScan Procedures Document

g. Internal Monitoring Daily QA Sheet

h. Procedure For Submission Of Internal Monitoring Summary Forms Into The Deployment Occupational & Environmental Health Surveillance (DOEHS) Data Portal

2. Site Operations

a. Personnel and Equipment: Personnel to be monitored and equipment to be used (or combination of equipment) are specified in references (a), (b) and (c). In addition, for sites with both the E600/SPA-3 probe (with additional Tungsten shielding) and fixed whole-body counters (e.g., AccuScan, FastScan, etc.) capabilities, it is the intent to perform Internal Monitoring (IM) utilizing the fixed scanner if possible because of the ability to measure the photon spectrum and the slightly lower Minimum Detectable Activity (MDA). However, both types of equipment may be required to be used based on the number of persons scheduled for a scan.

b. Site Manager: Each location where IM is performed shall have a lead person overseeing the team conducting IM. This person will be referred to as the IM Site Manager (IMSM). The IMSM shall be familiar with references (a) through (h).

i. The IMSM shall be responsible for ensuring that IM operations are performed in accordance with this directive and other specific procedures for the E600/SPA-3, AccuScan, and FastScan systems (references (d), (e), and (f)).

ii. The IMSM shall provide point of contact information including telephone number and e-mail address to the Yokosuka IMSM, the JSFJ/USFJ Surgeon's Office, and to the USPACOM Surgeon's Office.

iii. Each day prior to the start of the first shift, the IMSM shall call the Yokosuka IMSM to receive IM information updates and to provide a verbal

status of operations. If the Yokosuka IMSM cannot be reached, then the IMSM shall contact the JSFJ Surgeon's Office, or the PACOM Surgeon's Office if unavailable. If no contact is made, operations may proceed; however, additional attempts should be made for communication flow.

iv. At the end of each day, the IMSM shall send the Yokosuka IMSM the daily QA sheet (reference (g)).

3. Pre-Scanning Session Radiation Health Briefing

a. Each IMSM shall have a one-time pre-work briefing session with the Yokosuka IMSM regarding expectations for briefing and monitoring personnel performing operations in Japan. The briefing should include results and lessons learned from previous internal monitoring sessions, responses for likely questions arising during monitoring (from personnel being monitored and personnel operating the equipment), the set up of the location where personnel will be monitored, methods to control and protect personal information, and review of systems and tools to be used.

b. The IMSM briefing shall be documented by completing Attachment 1. Attachment 1 shall be electronically scanned and uploaded into the DOEHS Data Portal. IMSMs already installed shall fill-in and sign off Attachment (1) for continuing operations under the Open Availability Phase.

4. Internal Monitoring Procedure

This procedure is generic and applies to whatever system(s) are to be used.

a. Prior to performing internal monitoring, ensure that the AccuScan, FastScan or E600/SPA-3 systems are ready for use.

i. Using the most current version of the KAPL E600/SPA-3 procedure (Reference 2), ensure that the E600/SPA-3 unit is operating properly and that all the background measurements have been performed for each E600 to be used prior to and at the end of each shift. Individuals acting as E600 clean human phantoms shall be verified as free of internal plume radioactivity using a fixed whole body counter with copies of the whole body counter output attached to one of the E600/SPA-3 background datasheets at least once for record keeping purposes. Ensure that all background measurements taken at the beginning and end of the shift are recorded on the Background Data Sheet. This sheet shall be included in the data uploaded onto the DOEHS Data Portal.

CAUTION: The background measurements are very important and shall be performed with care in an area where there is minimal electromagnetic interference. The background measurements shall be performed using approved stands in the same positions/locations where personnel will be monitored.

ii. Using the appropriate NAVSEA-approved procedure, ensure the AccuScan or FastScan unit is operating properly and in calibration per references (e) and (f). Record the serial number, file spectrum name, MDA, and activity measurements on the E600/SPA-3 datasheet (Figure 2 in reference d).

iii. Ensure that the most recent version of the Internal Activity and Dose Calculation Tool (IADCT) is available, installed on a Government computer approved to store Personally Identifiable Information (PII), and operational with embedded macros working to load each person's data into the internal summary table. The most recent version of the IADCT shall be verified during the daily check-in with the IMSM at the Yokosuka IM site.

iv. Ensure that appropriate operators and support personnel are present for the monitoring session.

v. Care must be taken to ensure the spaces and equipment used for internal monitoring is maintained as free as possible from potential contamination from radioactivity in the environment. Surveys and wipe downs of equipment should be conducted frequently to accomplish this goal. Sticky pads should be used at the entrance of the counting space(s) and AccuScan/ FastScan to minimize entry of radioactivity into the space/equipment.

b. Introduce yourself to the person(s) to be monitored and explain why monitoring is taking place. Use the USPACOM approved pre-scan script to brief persons being scanned (Attachment (2)).

c. Enter the individual's personal information into the IADCT spreadsheet. If a Government computer approved for PII is not available, omit the social security number.

d. If using the E600/SPA-3 system, have personnel fill in Parts 1 and 2 of the E600/SPA-3 Personnel Monitoring Data Sheet while waiting to be scanned. Emphasize the need to print legibly and have personnel correct illegible entries.

i. The date for potential first exposure should be the date that the individual was exposed to his/her first plume (if known) or the date of arrival in theater (if plume exposure date is unknown).

ii. Answer questions regarding the form, paying particular attention to the use of KI while in theater.

e. All personnel should be wearing clean clothing. Previously contaminated clothing that has been washed is <u>not</u> acceptable. This is to prevent clothing contamination from being detected by the instruments as internal contamination. Military personnel shall be in clothing other then what was worn during missions in the theater during Operation TOMODACHI. Experience has shown that flight suits and uniforms worn during missions in contaminated areas may contain small amounts of radioactivity following several washings and shall not be worn during monitoring. If a person is wearing clothing that is identified not to be from

a clean source, request the person to remove their outer clothing and change into a Tyvek coverall (or equivalent). Explain the change of clothing is necessary to accurately perform the IM procedure. Regardless of the individual's preparation for internal monitoring, have him/her remove the following items prior to monitoring:

i. Coat
ii. Badge
iii. Shoes
iv. Hat or helmet
v. Portable equipment
vi. Neck Jewelry

f. Internally monitor the individual using an E600/SPA-3 unit, AccuScan or FastScan per references (d), (e), or (f), respectively.

i. If using an AccuScan or FastScan system, ensure that the scan includes the whole body and thyroid modes.
ii. Adults and children shorter than 4 feet (48 Inches) will be scanned using the E600/SPA-3 or the AccuScan. When using the AccuScan a small raiser for the individual to stand on can be used in order to create a clearance of at least 2 inches above the floor but no more than 12 inches. Utilize the AccuScan stationary mode with detectors centered 2 inches above the bottom of the sternum for individuals shorter than 4 feet (48 inches).
iii. If using an E600/SPA-3 unit for adults or children, perform a chest (males) /back (females) scan using appropriate probe/body geometry and ten (10) minute count times for each location. A stand shall always be used to ensure good counting geometry. Remember, once the E600/SPA-3 probe has been set up for the daily background count it should not be moved. Record the resulting chest/back count rates in Section 3 of the individual's Personnel Monitoring Data Sheet. If results for the chest/back scan are positive (≥MDA), conduct a scan of the thyroid following the appropriate procedures. IMPORTANT: if results for the chest/back scan are ≥ MDA, conduct a fixed scan for adults or another scan either using a different E600/SPA-3 instrument or AccuScan fixed system for children. Before performing the second child scan the possibility of contaminated clothing on the child shall be investigated and eliminated as a possibility. For any ≥MDA child result the IMSM shall immediately contact the Yokosuka IMSM or PACOM Surgeon General's Office for consultation. Note: infants are treated differently than children and are discussed in paragraph iv below.
iv. Infants will only be scanned using the E600/SPA-3. Infants are considered individuals that can be comfortably held on the chest of an adult. The responsible adult will be scanned first without the infant per reference d. If results for the responsible adult are <MDA, then the infant while being held by the same responsible adult will be scanned per reference d. If results for the responsible adult are ≥MDA they shall be scanned with a fixed system to

confirm the reading before measuring the infant. IMPORTANT: if infant IM results are ≥MDA, the process shall be repeated (i.e., the responsible adult and infant shall be re-scanned) using a different E600/SPA-3 unit to validate the positive reading).Before performing the second infant scan the possibility of contaminated clothing on the infant shall be investigated and eliminated as a possibility. For any positive infant result the IMSM shall immediately contact the Yokosuka IMSM or PACOM Surgeon General's Office for consultation.

v. Utilize the E600/SPA-3 exclusively for individuals with known or suspected claustrophobic issues.

g. IM data shall be recorded as follows depending on which instrument is used.

i. Open the IADCT spreadsheet and fill in the yellow highlighted blocks (spreadsheet cells) associated with that system. There are 20 informational blocks and several blocks for entering E600/SPA-3 and fixed scan count data. (Note: Informational data for all 20 blocks may not be available and should be left blank if unknown).

ii. If using the E600/SPA-3, enter the number of days between first exposure and IM date. Enter the background and measurement CPM data for chest/back. Note: Adult males and child males will use the background count for the clean human phantom chest count. Adult females and child females will use the background count for the clean human phantom back count. The background for infants will be the responsible adult count.

iii. If using the AccuScan or FastScan systems, enter the number of days between first exposure and IM date. Enter the machine-provided measured activity in nCi for I-131 thyroid, Cs-134 whole body, and Cs-137 whole body, and MDA values for I-131/Cs-134/Cs-137.

iv. If the fixed scanner system was used but no peaks were identified for I-131, Cs-134, or Cs-137 (i.e. less than MDA and no peaks for these nuclides are identified on the printouts) then enter zero (0) in the corresponding IADCT activity block.

v. For all systems, enter the scanned person's name, SSN, date of IM, name of person entering/reviewing data, date of the entry/review, and the "Group Association, Location of IM, and Comments" block. Omit the SSN if not using a Government computer approved for PII storage.

vi. Once all highlighted blocks (spreadsheet cells) are populated, the IADCT will indicate the individual's Committed Effective Dose Equivalent (CEDE) and Thyroid Committed Dose Equivalent (CDE) for the measurements entered. For most persons monitored the expected CEDE and CDE will be "< MDA" reflecting an intake less than the minimum detectable activity of the counting system.

vii. The IADCT spreadsheet only has room for 500 entries. A new IADCT spreadsheet shall be started each day and anytime that 500 entries are exceeded. Information from both shifts from a common day may be entered in a single spreadsheet.

viii. Using the computer mouse, select the electronic IADCT green button to populate the summary table with the data from the newest monitored person, while simultaneously clearing the spreadsheet entry boxes so the data for the next person can be entered.

ix. If the IM results indicate internally deposited radioactivity and it is determined that the individual may be wearing contaminated clothing, have the individual replace his/her outer clothing with Tyvek coveralls (or equivalent) and recount the individual.

x. If the individual was monitored with an AccuScan or FastScan system first and demonstrates internally deposited radioactivity, offer correlation internal monitoring using an E600/SPA-3 system to the extent permitted by operational limitations (sole purpose of obtaining data for correlation of the two systems).

a. If an individual is monitored using both a portable and fixed (AccuScan or FastScan) unit in succession due to an intake ≥MDA, the information should appear in the IADCT spreadsheet on a single line if possible. If this isn't possible, indicate the reason for the second measurement in its comment block.
b. If an individual monitored using an E600/SPA-3 unit shows an internal uptake ≥ MDA, follow the recommendations in section 4.f. above.

xi. Inform the scanned individual of his/her results using the USPACOM approved post-scan script (Attachment (3)). In addition, select the "Preliminary Results Report" tab on the IADCT, print out the automatically generated form, and give it to the individual (or responsible adult) scanned.

a. Be prepared to answer simple questions regarding the scanning procedure. Refer to the pre-briefing script whenever possible. For medical/health related concerns, recommend the individual follow up at their respective military healthcare provider.
b. Verify that all the monitored individual's questions have been answered prior to his/her departure from the monitoring location.

xii. If the monitored individual's CEDE is either significantly higher or lower than expected based on recent scanning results, inconsistent with results from other members of a common group, or inconsistent among scanning units (e.g. E600/SPA-3 and AccuScan or FastScan) check for a scanning system malfunction and request that the individual repeat the scan (Such a result is very unlikely and not expected for personnel supporting Operation TOMODACHI). Verify personnel met the showering and clothing criteria specified in paragraph 4.e.

a. In the unlikely event an individual's CEDE exceeds 500 mrem on two repeated scan attempts using a system (AccuScan, FastScan or E600/SPA-3) that is known to be functioning correctly, and the two

CEDEs are consistent, the individual must be referred to an Occupational Medicine physician or other appropriate provider. Occupational health clinics exist at the U.S. Naval Hospital Yokosuka and the Branch Health Clinic NAF Atsugi.

b. For any anomaly, unusual reading, or other event that might draw concern of a person scanned or from the media, the IMSM shall immediately contact the Yokosuka IMSM or PACOM Surgeon General's Office for consultation.

xiii. Any monitored individual expressing medical/health related concerns shall be referred to an MTF or military clinic for evaluation.

5. Post Scanning Session Requirements.

a. Ensure that all team members treat IM materials as PII before, during and after the scanning session.

b. Ensure AccuScan, FastScan and/or E600/SPA-3 units are properly shut down.

c. Collect all IM materials after the session's last individual is scanned.

d. Organize the supporting AccuScan or FastScan printouts, E600/SPA-3 Personnel Monitoring Data Sheets, and E600/SPA-3 Background Data Sheets for electronic scanning.

e. Ensure all IM data and quality control documentation is uploaded into the DOEHS Data Portal.

6. Data Management

a. The electronic IADCT spreadsheet only has room for 500 entries. A new IADCT spreadsheet shall be started each day and anytime that 500 entries are exceeded in a single day. Both shifts for a single day may be put on a one spreadsheet.

b. The Spreadsheet filename shall be written in the following format (spaces between descriptors are allowed for readability):

YYYY MM DD LOCATION IMSMNAME PERSONNELDESCRIPTOR

Where:
YYYY MM DD is the four digit year, 2 digit month, and 2 digit day on which IM was performed (EX 2011 04 09) Note: Always use two digits for month and day even if it is a number from 1 to 9, i.e., use a leading zero to make it two digits for numbers 1 thru 9.

LOCATION is a short abbreviation or acronym where IM was performed (EX CAMPZAMA)

IMSMNAME is the last name of the IMSM (EX JOHNSON)

PERSONNELDESCRIPTOR is a short abbreviation or acronym of the population monitored (EX USS RR)

c. Each electronic spreadsheet shall be password protected using the password: rho2011$ or another provided by the Yokosuka Site Manager during the daily call-in.

d. Review paper copies of E600/SPA-3 Personnel Monitoring Data Sheets and AccuScan / FastScan printouts for completeness, legibility, and technical accuracy. Check AccuScan and FastScan system results for unidentified peaks and other output anomalies and resolve any issues identified. Ideally, this should be done immediately after the individual is scanned so that a rescan can be performed if necessary.

e. Correct form errors using a single line strike through with initials and date.

f. The completed paper copies of the E600/SPA-3 Personnel Monitoring Data Sheets, E600/SPA-3 background data sheet, and AccuScan and FastScan printouts shall be electronically scanned into a series of PDF files daily or as operational conditions permit.

i. Use 300 DPI resolution for legibility and to minimize file size.
ii. Limit individual files to less than 5 MB in size for easier transmission. Winzip can be used to compress files as necessary.
iii. Each electronic PDF file shall be password protected using an Adobe program, Winzip (see attachment 5 for additional information if needed) or equivalent program with the password - rho2011$ or another provided by the Yokosuka IMSM during the daily call-in.
iv. Each PDF filename shall be written in the following format (spaces between descriptors are allowed for readability):

YYYY MM DD LOCATION IMSMNAME PERSONNELDESCRIPTOR

Where:
YYYY MM DD is the four digit year, 2 digit month, and 2 digit day on which the IM was done (EX 2011 04 09) Note: Always use two digits for month and day even if it is a number from 1 to 9, i.e., use a leading zero to make it two digits for numbers 1 thru 9.

LOCATION is a short abbreviation or acronym where the IM was performed (EX CAMPZAMA)
IMSMNAME is the last name of the IMSM (EX JOHNSON)

PERSONNELDESCRIPTOR is a short abbreviation or acronym of the population monitored (EX USS RR)

g. Create a new Compact Disc (CD) containing the final electronic IADCT spreadsheet and all the associated PDF files. Winzip all files (with password) associated with a single day into one winzip file on the CD. Group the files onto each CD to minimize the number of disks and maximize the number of files on each disk.

   i. If PDF files are not available because the worksheet paper copies cannot be scanned, then burn a CD containing the electronic IADCT spreadsheet.
   ii. Label the CD with Spreadsheet file name and mark appropriately for PII including “UNCLASSIFIED FOUO”
   iii. Mail the CDs and all paper copies by traceable means (e.g., registered mail, certified mail, or other means) to the Naval Dosimetry Center (NDC) at:

Naval Dosimetry Center
Bldg 4/6
Attention: Internal Monitoring
8901 Wisconsin Ave
Bethesda, MD
20889-5614

The NDC will provide acknowledgement that the submission was received.

h. Individual Internal Monitor Site Managers shall comply with the following rules for shipping paper and CD sensitive PII materials:

   i. Make a copy of all paper and electronic files and store locally in a safe place until verification can be made that Naval Dosimetry Center has received all IM materials.
   ii. For shipping paper and CD's use two opaque containers (envelope, pouch, package, and/or box) to form an inner and outer package.
   iii. There shall be no indications on the outer or inner container that it contains PII.
   iv. Both containers (inner and outer) shall be sealed to prevent inadvertent opening and to show signs of tampering.
   v. Both containers (inner and outer) shall be labeled with the name and address of the recipient and sender and labeled somewhere with "U.S. Government Property, If Found Return to the Sender". A contact phone number shall be included such that the phone as voice mail or is manned 24/7.
   vi. The inner and outer containers may be those provided by shipping vendors (for example, FEDEX, UPS, or USPS) but containers shall be new and not reused.

vii. Containers shall be sent by traceable means, such as a receipted delivery service (i.e., Return Receipt, Certified or Registered mail) or a tracking service (e.g., "Track & Return.") to ensure secure delivery is made to the appropriate recipient.

viii. DVDs and CDs shall be labeled "FOUO Property of US Government If Found Return To (sender's address)". A contact phone number shall be included such that the phone has voice mail or is manned 24/7.

ix. Electronic data on DVDs and CDs shall be encrypted with a government approved program such as when possible (for example using dataguard). All files on the DVD and CD shall at least be password protected/encrypted using WINZIP 9.0 or later. Passwords shall not be available anywhere in or on the package, DVD, or CD.

i. As soon as practicable, all IMSMs shall obtain access to the DOEHS Data Portal using the process described in Attachment 4. DOEHS will serve as the data repository for electronic versions of IADCT spreadsheets and supporting PDF documents currently forwarded to USPACOM and the Naval Dosimetry Center (NDC). Until the responsible IM establishes an account and starts placing IM information in DOEHS, he/she shall e-mail each final IADCT spreadsheet and supporting document PDF files created via separate E-mails to Lisa.Kennemur@med.navy.mil (POC at NDC) for electronic archiving. E-mails shall be sent daily or as soon as operational conditions permit. If these capabilities are not available locally, provide CDs containing the IADCT spreadsheet and supporting PDF files to the IMSM at the Yokosuka site for electronic submission.

j. Upon conclusion of IM operations at a particular location, erase all electronic files after the information has been transmitted and verified received.

7. Equipment Support. Equipment support and repair should be coordinated through Puget Sound Naval Shipyard; the point of contact is Mr. Eric Gough at 080-1331-1720.

8. Documentation of Pre-Scanning Session Radiation Health Briefing

a. The following person has been given a one-time pre-work briefing regarding expectations for internally monitoring personnel involved in Operation TOMODACHI.

b. The briefing included results and lessons learned from previous internal monitoring sessions, responses for likely questions arising during monitoring (from personnel being monitored and personnel operating the equipment), set up of the location where personnel will be monitored, methods to control and protect personal information, and review of systems and tools to be used.

Printed Name of Person Acting as Internal Monitoring Site Manager (IMSM):

Last, First, Middle Initial:_____

E-mail Address of IMSM:_____

Telephone Contact Number of IMSM:_____

IMSM Signature and date of Signature:_____

Printed Name of Person Providing One-Time Pre-Work Brief:

Last, First, Middle Initial:_____

Signature and date of Signature:_____

PLEASE SCAN AND FORWARD TO USPACOM SURGEON'S OFFICE

Attachment (1)

9. Briefing Information

a. Pre-scan briefing.

[Script for internal monitoring of Internal Deposition of Radioactive Material to be presented and read to personnel upon arrival at site]

Internal monitoring is a way to determine if radioactivity was taken into the body. This voluntary screening is being offered to address your concerns regarding personal radiation exposure. Since the March 11th earthquake and tsunami, the Department of Defense, along with the US Department of Energy, the US Nuclear Regulatory Commission and the Government of Japan have been carefully monitoring levels of radioactive materials released from the Fukushima Power Plant. Environmental radioactivity levels in your area have been, and continue to be very low. To date, we have performed internal monitoring on over 6000 Department of Defense personnel who were considered to have a higher potential for being exposed to radiation. Approximately 98% of these individuals showed no detectable level of radiation above background levels. Among the 2% with detectable levels of radiation, none resulted in a dose higher than 25 millirem. This radiation dose is approximately equal to the dose received from 2 and ½ chest x-rays.

Because of the internal monitoring results to date, we neither recommend nor require this screening. We are offering this screening in order to address your personal health concerns and assure your wellbeing.

The screening is painless, non-invasive and does not generate any radiation. The process takes about 20 minutes, for which you will need to remain still. The screening may use either a fixed or a portable internal monitoring system depending on system availability. If any radioactivity is detected on a portable internal monitoring system, you will be given the opportunity to have the results confirmed with a fixed internal monitoring system. After the screening, you will be given written documentation of your preliminary results and be provided with an explanation of them with regard to your long-term health and safety. These preliminary results will be sent to the Naval Dosimetry Center for quality assurance and confirmation.

The internal monitoring systems are very sensitive and will detect very small amounts of radioactivity, including background radioactivity from the environment. It is important to remember that small amounts of radioactive materials are naturally found in our bodies as well as all around us - in the environment and in nearly all food and water. This screening will help identify any levels above that background. It is important to disclose any radioactive material administered as part of a medical diagnosis or procedure as this will interfere with the scanning results. Also, please let me know if you have concerns regarding standing in a semi-confined space.

Do you have any questions at this time? Attachment (2)

REMINDER: It is important to emphasize avoiding IM individuals with potentially contaminated clothing. Review requirements of paragraph 4(e) above with the individual prior to initiating IM procedures.

b. Post-scan briefing.

[Scripts for internal monitoring of Internal Deposition of Radioactive Material to be presented and read to personnel upon completion of monitoring based on results]

i. (For monitoring results less than Minimum Detectable Activity (MDA)):

"Your monitoring results showed that even the most sensitive equipment did not detect any radioactive material above natural levels. Based on these results, no further evaluation is required."

ii. (For E600/SPA-3 monitoring results that are initially ≥ MDA):

"Your/ Your child's initial results indicate that a very small amount of radioactivity was detected. However, there are other possibilities for this result so a rescan will be necessary with a different E600/SPA-3 instrument or fixed scanner for verification. After the re-scan, you will be informed of the preliminary results".

"There is no health concern because the amount of potential radioactivity taken into the body released from the Fukushima Daiichi Power Plant that reached US DoD populations was very small. However, if you have questions or concerns regarding you/your child's health, you should discuss these concerns with your health care provider".

"We will conduct another scan (Note to IMSM: read the one that applies; however, don't offer option c unless the individual requests an alternate time);

a. at this time using another E600/SPA-3 instrument.
b. at this time using one of our fixed scanners. If necessary, transportation will be provided.
c. at a mutually convenient time and date".

iii. (For validated monitoring results ≥ MDA but producing combined CEDEs less than or equal to 500 millirem):

"Your monitoring results showed that a very small amount of radioactive material was detected in your body/(your child's body). The radiation dose from this amount of radioactivity is less than what someone would receive living in Denver, Colorado for a year. This low level of radiation is not medically significant and no adverse health effects are expected. The very small amount of radioactive material will break down naturally in the body. It poses no threat to you/(your child) or members of your household. There is no need to change any of your/(your child's) daily activities and no further medical evaluation or treatment is required."

Attachment (3)

iv. (For validated monitoring results producing combined CEDEs in excess of 500 millirem):

"Your/(Your child's) monitoring results indicated that radioactive material was detected during the testing. The level of radioactivity detected should not cause any health problems. However, we are referring you to the Occupational Health Clinic at the hospital. An Occupational Medicine physician will examine your results to determine if further testing and/or follow-up is required, and will also be able to answer any other questions you may have. This is not a medical emergency and you are not in any danger. The small amount of radioactive material will break down naturally in the body. It poses no threat to you (your child) or members of your household. There is no need to change any of your (your child's) daily activities."

9. Procedure For Submission Of Internal Monitoring Summary Forms Into The Deployment Occupational & Environmental Health Surveillance (DOEHS) Data Portal.

a. Individuals undergoing internal monitoring with the AccuScan, FastScan or E600/SPA-3 systems shall have the hard copy supporting data forms electronically scanned in to a PDF file. These PDF files shall be uploaded into the DOEHS Data Portal.
b. Utilizing the DOEHS Data Portal requires the establishment of an account. The DOEHS website can be accessed at https://doehsportal.apgea.army.mil/doehrs-oehs. To establish an account, go to the "User Menu" tab and select "Account Request." Accounts take approximately 1 to 2 days to be processed.
c. Detailed instructions for establishing an account and submitting data are located on a PDF file accessed at: http://phc.amedd.army.mil/PHC%20Resource%20Library/DOEHS_Portal_brochure_11-2010-02.pdf. The PDF file is produced by the U.S. Army Public Health Command and can also be accessed through: http://phc.amedd.army.mil/topics/envirohealth/hrasm/Pages/dataportal.aspx
d. To ensure all internal monitoring data is filed in a common data portal location, persons submitting the Internal Monitoring Summary Forms shall follow the following guidance:
Go to the "Document Library" tab and select "Submit Document."

i.	Operation:	"Tomodachi"
ii.	Country:	"Japan"
iii.	Location:	input location of the internal monitoring site. If not listed, a location may be added.
iv.	Document Type:	"Internal Monitoring Results"
v.	Classification:	"For Official Use Only"
vi.	Date of data (start)	input date of internal monitoring
vii.	Date of data (end)	(same as start date)
viii.	File Title	"Individual Internal Monitoring"
ix.	File Summary	Input individual's unit/command, address
x.	Keywords:	"Internal Monitoring," "Accuscan" "Fastscan" "E600" as appropriate
xi.	File to submit	upload the PDFs for the day's internal monitoring. See following page for encrypting data files

e. Those having difficulty with the database can contact the following DOEHS Data Portal Technicians for support:

Mr. Brad Huchens: brad.hutchens@us.army.mil
Ms. Cristine Maranville: cristine.maranville@us.army.mil

Attachment (4)

10. Procedure for Encrypting Data Files for Submission to DOEHS Data Portal

a. This procedure shall be used to encrypt files that are to be uploaded to the Deployment Occupational and Environmental Health Surveillance Data Portal (DOEHS)

i. Open the folder containing the files to be uploaded to DOEHS.

ii. Select the files then right click and mouse over to winzip "Add to Zip file…" (see Figure 1)

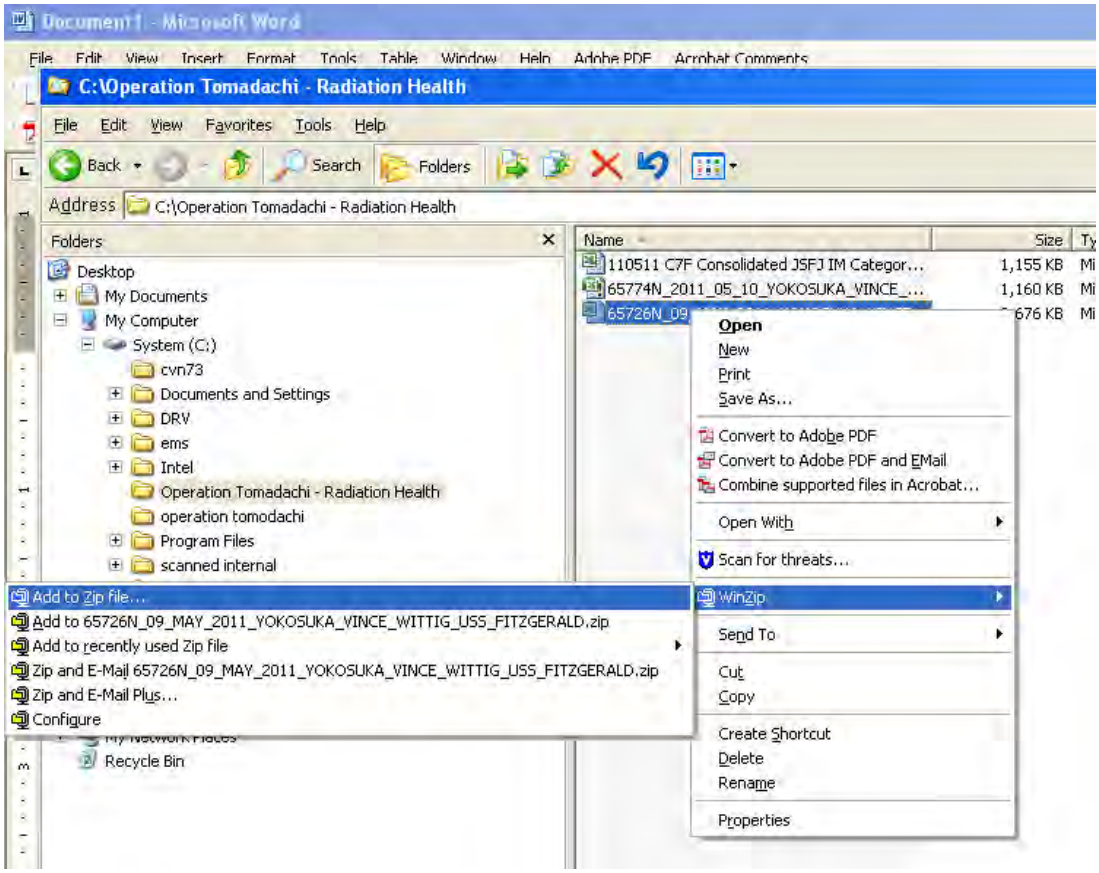

Figure (1) Adding selected files to WinZip

Attachment (5)

iii. A menu box will open. Select "Encrypt added files" and generate the file name as prescribed in the instruction in the "Add to archive" dialog box. (see Figure 2)

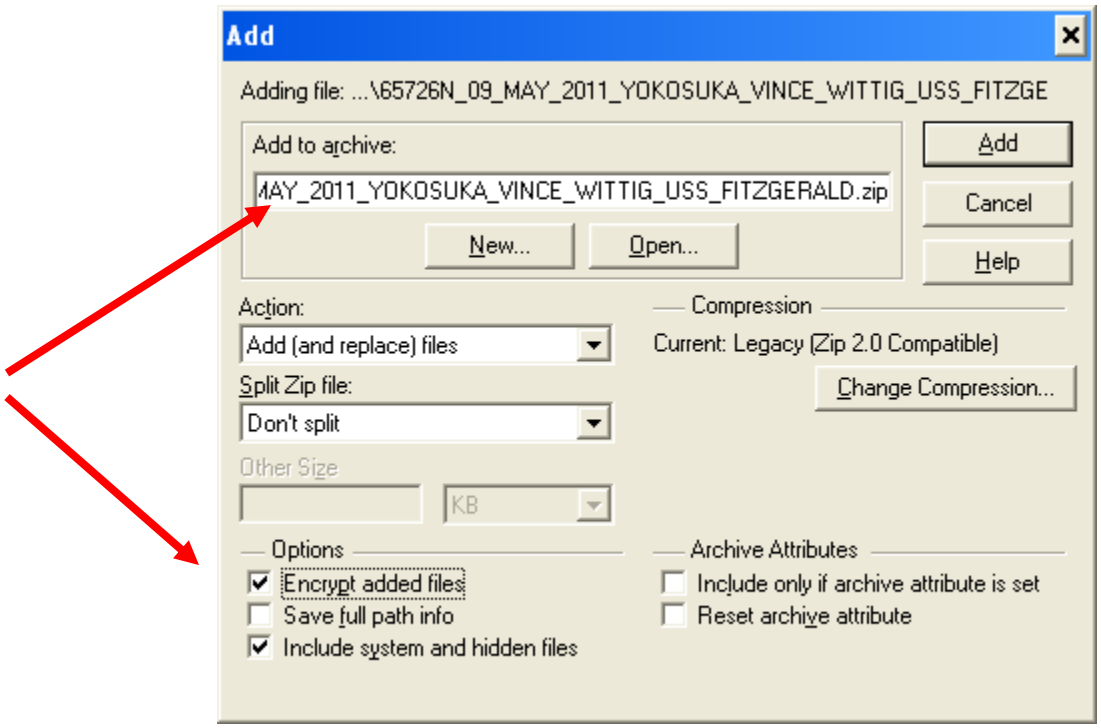

Figure (2) File name and Encryption dialog

iv. Select "Add" button and an encrypt dialog box will open. (see Figure 2)

v. Enter the password prescribed in the instruction. Then Re-Enter the password. (see Figure 3)

vi. Select "256 bit AES encryption (stronger)" and press "OK" (see Figure 3)

vii. The file will be generated and ready for upload.

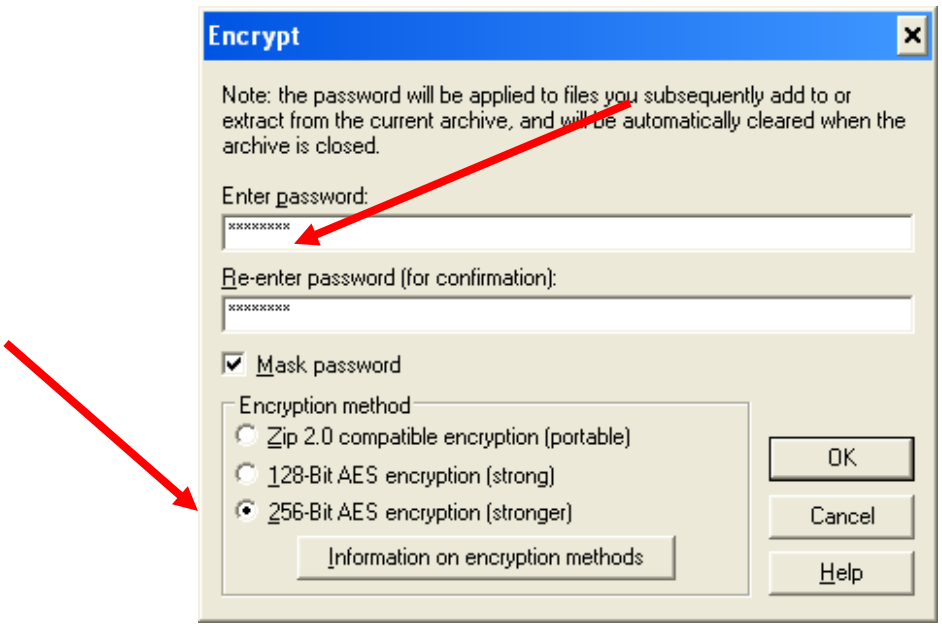

Figure (3) File name and Encryption dialog

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Appendix C.

USPACOM Guidance for Identification and Screening of Personnel

Subject: GUIDANCE FOR IDENTIFICATION AND SCREENING OF PERSONNEL OPERATING ISO OPERATION TOMODACHI CHANGE 1
Originator: JOINT SUPPORT FORCES JAPAN(UC)
DTG: 200549Z Apr 11
Precedence: IMMEDIATE
DAC: General
To: PACAF CC(UC), I CORPS (FWD) AND USARJ COMMAND CENTER(MC), COMNAVFORJAPAN YOKOSUKA JA(UC), COMMARFORJ G-3(UC), COMSEVENTHFLT, 5AF CC(UC), COMSOCPAC HONOLULU HI(UC)
cc: HQ USPACOM J3(UC), HQ USPACOM SJFHQ(UC), CDR USPACOM HONOLULU HI(UC), COMPACFLT PEARL HARBOR HI, COMMARFORPAC CMD OPS CNTR(UC), USARPAC COMMAND CENTER(UC), USFJ COMMAND CENTER(UC), CG III MEF(UC), AMEMBASSY TOKYO, CG 3RD MARDIV(UC), 13AF A6(UC), 13AF PA(UC), COMUSJAPAN YOKOTA AB JA, JTF 505(UC)

UNCLASSIFIED//
OPER/TOMODACHI/
MSGID/GENADMIN/JSF/-/APR//

SUBJ/GUIDANCE FOR IDENTIFICATION AND SCREENING OF PERSONNEL OPERATING ISO OPERATION TOMODACHI CHANGE 1//

REF/A/LTR/PACOMJ07/08APR11//
REF/B/MSG/COMJSF/160730ZAPR11//
REF/C/MSG/COMJSF/181000ZAPR 11//

NARR/REF A IS THE CONCEPT OF OPERATIONS FOR INTERNAL MONITORING OF DEPARTMENT OF DEFENSE PERSONNEL PARTICIPATING IN OPERATION TOMODACHI IDENTIFICATION. REF B IS A COMJSF MESSAGE REGARDING GUIDANCE FOR IDENTIFICATION AND SCREENING OF PERSONNEL OPERATING ISO OPERATION TOMODACHI. REF C IS CHANGE 4 TO OPERATION TOMODACHI SUPPLEMENTAL GUIDANCE FOR PERSONNEL/OPERATIONS IN RADIOLOGICAL ENVIRONMENTS. //

RMKS/
1. INTENT.

1.A. THIS GUIDANCE IS DIRECTIVE. THIS MESSAGE IMPLEMENTS REF A AND SUPERSEDES REF B IN ITS ENTIRETY.

2. SITUATION.

2.A. THE 11 MAR 2011 EARTHQUAKE AND TSUNAMI CAUSED SIGNIFICANT DAMAGE TO THE FACILITIES AT THE FUKUSHIMA DAIICHI NUCLEAR POWER PLANTS, RESULTING IN THE RELEASE OF SIGNIFICANT QUANTITIES OF RADIOACTIVE MATERIAL. U.S. FORCES PARTICIPATING IN HUMANITARIAN ASSISTANCE MISSIONS ASSOCIATED WITH THIS EVENT HAVE BEEN POTENTIALLY EXPOSED TO ENVIRONMENTAL RADIOACTIVE MATERIAL AS A RESULT OF THIS RELEASE. HUMAN RADIATION DOSE IS BASED ON TWO COMPONENT SOURCES. THE FIRST EXPOSURE COMPONENT IS EXTERNAL DOSE. EXTERNAL DOSE CAN BE ACCURATELY MEASURED USING PERSONAL DOSIMETERS REQUIRED PER REF C. THE SECOND COMPONENT DEPENDS ON DOSE TO SPECIFIC ORGANS AND THE WHOLE BODY AS A

RESULT OF RADIOACTIVITY TAKEN INTO THE BODY BY INHALATION OR INGESTION. THIS COMPONENT IS DETERMINED BY MEASURING INTERNAL RADIOACTIVITY BY MEANS OF SPECIALIZED EQUIPMENT AND CANNOT BE EFFECTIVELY DETERMINED USING PERSONAL DOSIMETERS OR TYPICAL DIRECT RADIATION SURVEY INSTRUMENTS (RADIACS). FOR REACTOR ACCIDENTS, UPTAKE OF I-131 IN THE THYROID AND CS-134 AND CS-137 IN THE LUNGS ARE OF PRIMARY CONCERN FOR DETERMINING ORGAN AND WHOLE BODY DOSES. ACCORDINGLY, IT IS APPROPRIATE TO INITIATE AN INTERNAL MONITORING PROCESS TO DETERMINE THE EXTENT OF POTENTIAL INTERNAL CONTAMINATION AMONG DOD PERSONNEL ASSIGNED IN JAPAN WHO HAD ELEVATED RISK OF EXPOSURE.

3. IDENTIFICATION OF PERSONNEL WITH ELEVATED RISK OF RADIOACTIVE INTERNAL CONTAMINATION.

3.A. WHOLE BODY SCANNERS PROVIDE A SENSITIVE MEANS TO DETECT SMALL TRACES OF RADIOACTIVE INTERNAL CONTAMINATION. IDENTIFICATION OF PERSONNEL AT HIGHEST RISK FOR INTERNAL CONTAMINATION WOULD ENABLE A STRATIFIED MEANS TO BEST USE THIS VERY LIMITED RESOURCE. BY TAKING THESE ACTIONS, SERVICE COMMANDS CAN GET PERSONNEL AT GREATEST RISK OF INTERNAL CONTAMINATION RAPIDLY PRIORITIZED FOR THIS ACCURATE MEASUREMENT FOR POTENTIAL INTERNAL CONTAMINATION.

3.B. SERVICE COMMANDS WILL IDENTIFY PERSONNEL SERVING DURING OPERATION TOMODACHI IN THE FOLLOWING CATEGORIES:

3.B.1. CATEGORY I: ALL MILITARY AND DOD CIVILIAN PERSONNEL WHO CONDUCTED OPERATIONS WITHIN THE JSF-J WARM OR HOT ZONES DEFINED AS: 1) THE AREA WITHIN 125NM OF THE FUKUSHIMA DAIICHI REACTOR PLANT FROM 14MAR11 TO 14APR11 AND 2) THE AREA WITHIN 80KM OF THE FUKUSHIMA DAIICHI REACTOR PLANT AFTER 14APR11.

3.B.2. CATEGORY II: ALL PERSONNEL WITH DOCUMENTED RADIOLOGIC SKIN CONTAMINATION AS A RESULT OF GROUND, AIR OR DECONTAMINATION OPERATIONS.

3.B.3. CATEGORY III: ALL MILITARY AND DOD CIVILIAN PERSONNEL, INCLUDING HELICOPTER CREWS FROM ALL SERVICES, WHO HAVE FLOWN MISSIONS THROUGH KNOWN PLUMES.

3.B.4. CATEGORY IV: ALL MILITARY AND DOD CIVILIAN PERSONNEL WHO WERE INVOLVED IN DECONTAMINATION OPERATIONS FOR AIRCRAFT, SHIPS, EQUIPMENT AND PERSONNEL.

3.B.5. CATEGORY V: ALL MILITARY AND DOD CIVILIAN PERSONNEL SUPPORTING SHIP CREWS, INCLUDING NUCLEAR TRAINED PERSONNEL, WHO OPERATED FROM SHIPS OR AIRCRAFT AND WERE WITHIN EITHER ZONE DESCRIBED IN PARAGRAPH 3.B.1 ABOVE.

3.B.6. CATEGORY VI: MILITARY AND DOD CIVILIAN PERSONNEL DEEMED APPROPRIATE BY JOINT SUPPORT FORCE (JSF-J), WITH USPACOM CONCURRENCE.

3.B.7. IF PERSONNEL FALL INTO MORE THAN ONE CATEGORY, REPORT THE MOST SIGNIFICANTLY IMPACTING (LOWEST CATEGORY NUMBER) TO HELP DETERMINE SUBSEQUENT ACTIONS DESCRIBED IN PARA 4 BELOW.

4. SERVICE COMMANDERS SHALL COMPLETE THE IDENTIFICATION OF PERSONNEL REQUIRED BY PARA. 3 NO LATER THAN 30 APR 11. REPORT RESULTS TO JSF-J.

5. SERVICE COMMANDERS WILL COORDINATE WITH JSF-J TO ARRANGE FOR SCREENING AND INTERNAL MONITORING FOR IDENTIFIED PERSONNEL BASED ON CATEGORY

PRIORITIZATION AND CONOPS TO BE FORWARDED SEPCOR.

6. SERVICE COMMANDERS WILL REPORT SCREENING AND INTERNAL MONITORING PROGRESS OF IDENTIFIED PERSONNEL TO JSF-J WEEKLY UNTIL COMPLETE.

7. JSF-J POC FOR INTERNAL MONITORING, SCREENING, AND DOSIMETRY ISSUES IS LT DAVID LANE, USFJ-CAT-MEDICAL@USFJ.MIL, DSN 315-225-4712/4715/2228.//
BT

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Appendix D.

E-600/SPA-3 Internal Monitoring Procedure (Final - July 21, 2011)

This appendix displays the document entitled INTERNAL MONITORING PROCEDURE FOR USE WITH THE E600/SPA-3 (Rev 21 Jul 2011).

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INTERNAL MONITORING PROCEDURE FOR USE WITH THE E600/SPA-3 (Rev 21 Jul 2011)

Note: This instruction is meant to be used with the following instruction;

"HEALTH PHYSICIST DIRECTIVE FOR INTERNALLY MONITORING PERSONNEL PARTICIPATING IN OPERATION TOMODACHI (Rev 21 July 2011)"

Persons operating the E600/SPA-3 instrument (with additional Tungsten shielding) shall read this instruction prior to performing scans with the E600/SPA-3 and follow the combined set of instructions which are mutually consistent. Any questions or concerns should be directed to the Internal Monitoring Site Manager (IMSM) at Yokosuka or to the PACOM Surgeon's Office at 808-477-7854.

1. GENERAL INFORMATION

1.1. The E600 portable digital RADIAC is used with a SPA-3 detector. The SPA-3 is a 2 x 2 inch NaI(Tl) gamma scintillation detector. Additional shielding is provided by wrapping the SPA-3 probe with two 6 x 12 inch, ½ inch-thick Tungsten sheets.

Configuration of shielding

1.2. CAUTION: The SPA-3 detector, SMARTPAK (which stores the calibration information), and E600 are a matched set. Each matched set has been clearly labeled. Do NOT separate or mix and match SPA-3s, SMARTPAKs, and E600s.

1.3. CAUTION: Batteries (three "C" cells) - Battery indicator can be seen when the rotary switch is in the "Check" position:

1.3.1. Batteries should be replaced if indicator shows less than 25%. Ensure E600 is turned Off when replacing the batteries.

1.3.2. If indicator drops below 25% while in use, finish the internal monitoring, and ensure the batteries are replaced promptly.

1.3.3. If batteries drop below 10% stop using the meter and replace the batteries.

1.4. CAUTION: If disconnecting the cable or detector ensure the E600 is turned Off.

1.5. Three separate channels are calibrated on the E600/SPA-3. All three channels are calibrated identically and measure energies of ~88 keV to ~2 MeV. The E600 will display the Greek gamma symbol "γ" for all three channels. The only difference between each channel is the scaler count time. Press the "Chnl" key on the E600 handle to switch between channels.

Channel	Scaler Count Time (min)
1	10
2	20
3	30

1.6. Ensure the detector is used with either a standard 3ft or 5ft smart cable.

1.7. When the E600 is initially powered ON, the instrument performs a number of internal self-tests. These are invisible to the user and no test results are displayed. If any of the tests fail, the unit simply indicates "FAIL" and then won't operate. The instrument also checks the calibration date and will not operate if past the calibration due date.

1.8. All measurements obtained with this procedure will be performed with the rotary switch turned to "Scaler". For that reason, the position of the response time toggle (slow, med, or fast) is irrelevant.

1.9. The E600 shall be in Gross mode for internal monitoring. If the word "Net" is displayed to the left of the measurement on the E600, press the "Gross/Net" switch on the E600 to exit Net mode.

1.10. The user may press the light switch on the E600 handle to illuminate the display as needed. The display will remain lit for ~5sec.

1.11. The E600 has been calibrated with Auto-Ranging turned on; therefore, the range switches are deactivated. The E600 will automatically switch to the appropriate scale and beep when changing scales.

1.12. The user may press the Speaker button on the E600 to toggle the audio for the individual counting events off or on.

1.13. The background data sheet, Figure 1, is located at the end of this document and is used to record the background data for a given E600/SPA-3. One Figure 1 should be used for the entire duration of internal monitoring with a particular E600/SPA-3; use continuation sheets as needed. All background data sheets shall be maintained as permanent records in hard copy form and sent to the Naval Dosimetry Center for final archiving.

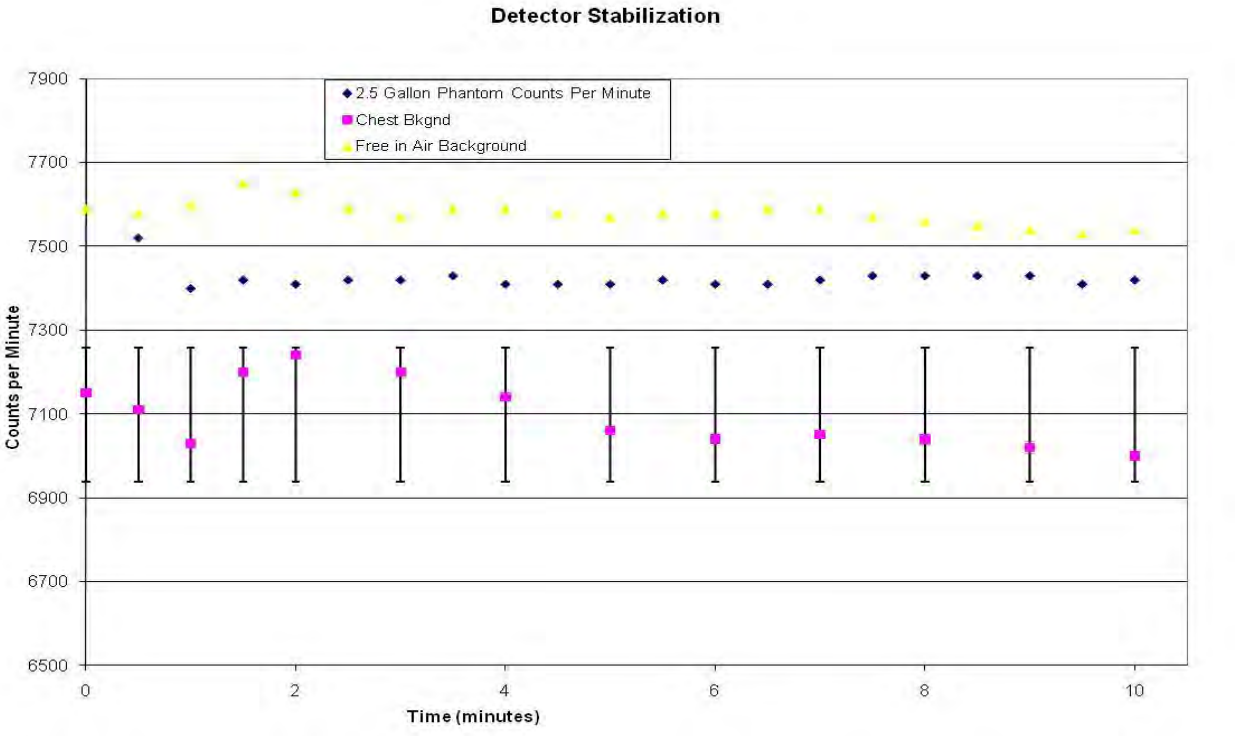
1.14. The personnel monitoring data sheet (Figure 2), is located at the end of this document. All personnel monitoring data sheets shall be maintained as permanent records in hard copy form and sent to the Naval Dosimetry Center for final archiving.

1.15. The SPA-3 probe shall be held in same position for both background measurement and personnel monitoring by a probe stand as shown in Figure 3. This is to stabilize the probe and provide a repeatable counting geometry.

2. BACKGROUND MEASUREMENTS

2.1. This procedure assumes a counting shift is approximately 8 hours and that it is possible for multiple counting shifts to occur in a 24 hour period. **As a minimum, a set of background measurements shall be performed for each E600/SPA-3 in use at the beginning of each counting shift prior to monitoring personnel and at the end of each counting shift upon completion of personnel monitoring.** The frequency of this measurement may need to be adjusted if experience shows that background varies more than 10% in a 24 hour period. If so, perform background measurements at the start of each counting shift prior to monitoring personnel and at a frequency deemed appropriate based on past data and experience (e.g. every four hours while monitoring personnel).

2.2. Obtain the background data sheet (Figure 1) associated with the E600/SPA-3. If the existing background data sheet is not readily available, obtain a new Figure 1 and record the E600 and SPA-3 serial numbers. Warm up the E600/SPA-3 system by leaving it on for 10 minutes prior to start of the background measurement. The instrument should always be running at least 10 minutes prior to taking any measurement. The following graph illustrates how system output varies as a function of the warm-up time.



2.3. The personnel monitoring area should have a low background radiation level (ideally less than 6000 CPM) and be located away from obvious sources of radioactivity and electromagnetic interference.

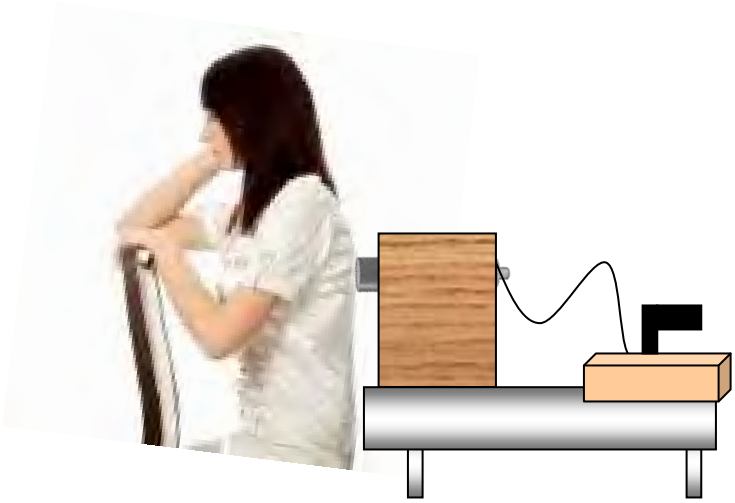
2.4. Using an individual known to be "clean" of man-made external and internally deposited radioactivity thru the use of a recent FastScan or AccuScan internal monitoring on the person, place the SPA-3 probe to the Chest of this individual per Section 5.3 of this procedure. **For a particular E600/SPA-3 set, the same person shall be used as the clean human phantom for the chest, back, and thyroid background measurements.**

2.5. Turn/ensure the rotary switch to "Scaler". Note this may start a counting cycle that can be ignored.

2.6. Set/ensure the E600 to channel 2, which has a 20 minute count time. This can be accomplished by depressing the "Chnl" key on the E600 handle to cycle through the three channels. Note this may start a counting cycle that can be ignored. Select channel 2 by observing the count time on the lower right of the display and stop at the 20 minute count time.

2.7. Depress the star key on the E600 to officially start the 20 minute background counting cycle. Note that the timer on the lower right of the display will begin counting down. Record the date and time the background was started on Figure 1.

2.8. At the completion of the 20 minute counting cycle, record onto Figure 1 the "Chest" background count rate displayed on the E600. If a "Back" background count is required for internally monitoring females then repeat steps 2.4 thru 2.8 but position the probe on the back of the clean human phantom person as shown below.



Placement of SPA3 Probe on Female

2.9. If a thyroid background count is needed follow steps 2.9 thru 2.13, otherwise skip to step 2.14. Using a same individual known to be "clean" of man-made external and internally deposited radioactivity in step 2.4 above, place the SPA-3 probe to the thyroid in accordance with Section 3 of this procedure.

2.10. Turn/ensure the rotary switch to "Scaler". Note this may start a counting cycle that can be ignored.

2.11. Set/ensure the E600 to channel 2, which has a 20 minute count time. This can be accomplished by depressing the "Chnl" key on the E600 handle to cycle through the three channels. Note this may start a counting cycle that can be ignored. Select channel 2 by observing the count time on the lower right of the display and stop at the 20 minute count time.

2.12. Depress the star key on the E600 to officially start the 20 minute background counting cycle. Note that the timer on the lower right of the display will begin counting down. Record the date and time the background was started on Figure 1.

2.13. At the completion of the 20 minute counting cycle, record onto Figure 1 the "Thyroid" background count rate displayed on the E600.

2.14. With the SPA-3 probe positioned in the probe stand "free in air" as shown in Figure 3.

2.15. Turn/ensure the rotary switch to "Scaler". Note this may start a counting cycle that can be ignored.

2.16. Set/ensure the E600 to channel 2, which has a 20 minute count time. This can be accomplished by depressing the "Chnl" key on the E600 handle to cycle through the three channels. Note this may start a counting cycle that can be ignored. Select channel 2 by observing the count time on the lower right of the display and stop at the 20 minute count time.

2.17. Depress the star key on the E600 to officially start the 20 minute background counting cycle. Note that the timer on the lower right of the display will begin counting down. Record the date and time the background was started on Figure 1.

2.18. At the completion of the 20 minute counting cycle, record onto Figure 1 the "Free in Air" background count rate displayed on the E600.

2.19. No special child background counts will be taken. The background counts for adults are the best available background counts for children.

2.19.1. For the purposes of this instruction, a child is considered an individual at age 17 and younger. Note: Be sure to enter fractional ages to ensure accurate dose calculations. The background associated with the clean human phantom (chest) and (back) will provide the background for a male and female child respectively.

2.19.2. For the purposes of internal monitoring, an infant is considered a child who can be comfortably held on the chest of an adult. The counts associated with the responsible adult male (chest) or female (back) will provide the background for an infant.

3. PERSONNEL MONITORING

3.1. Obtain the personnel monitoring data sheet (Figure 2) and complete Parts 1 and 2 for the individual being monitored.

3.2. In Part 3 record the following: date and time of monitoring, record the serial numbers of the E600 and SPA-3, transcribe the most recent background data from Figure 1 (background date and time and counts per minute), and enter the count data.

4. PERSONNEL MONITORING – THYROID

4.1. This procedure is necessary only when a chest or back internal monitoring result is above MDA.

4.2. Turn/ensure the rotary switch to "Scaler". Note this may start a counting cycle that can be ignored.

4.3. Set/ensure the E600 to channel 1, 2, or 3 as directed, which have 10, 20, and 30 minute count times respectively. Normal count time is 10 minutes (Channel 1).

4.3.1. This can be accomplished by depressing the "Chnl" key on the E600 handle to cycle through the three channels. Note this may start a counting cycle that can be ignored. Select the appropriate channel by observing the count time on the lower right of the display and stop at the appropriate count time.

4.3.2. Record the count time in the thyroid section of Part 3 of the personnel monitoring data sheet (Figure 2).

4.4. Position the SPA-3 detector against the lower half of the front of the individual's neck.

4.5. Depress the star key on the E600 to officially start the counting cycle. Note that the timer on the lower right of the display will begin counting down.

4.6. At the completion of the counting cycle, record onto Part 3 of the personnel monitoring data sheet (Figure 2) the thyroid count rate displayed on the E600.

5. PERSONNEL MONITORING – CHEST (males, children), BACK (females)

5.1. Turn/ensure the rotary switch to "Scaler". Note this may start a counting cycle that can be ignored.

5.2. Set/ensure the E600 to channel 1, 2, or 3 as directed, which have 10, 20, and 30 minute count times respectively. Normal count time is 10 minutes (Channel 1).

5.2.1. This can be accomplished by depressing the "Chnl" key on the E600 handle to cycle through the three channels. Note this may start a counting cycle that can be ignored. Select the appropriate channel by observing the count time on the lower right of the display and stop at the appropriate count time.

5.2.2. Record the count time in the chest section of Part 3 of the personnel monitoring data sheet (Figure 2).

5.3. Do the following for males or females:

5.3.1. For males, position the end of the SPA-3 detector in contact with the chest such that the centerline of the detector passes through the effective center of the lungs. Note the effective center of the lungs is located two inches above the base of the sternum. Note the base of the sternum is the apex where the rib cage forms an upside down letter "V"; position the end of the SPA-3 detector two inches above this point.

5.3.2. For females, position the end of the SPA-3 detector in contact with the back such that the centerline of the detector passes through the effective center of the lungs. Note the effective center of the lungs is located two inches above the base of the sternum. Note the base of the sternum is the apex where the rib cage forms an upside down letter "V"; position the end of the SPA-3 detector at the same height but from the back.

5.4. Depress the star key on the E600 to officially start the counting cycle. Note that the timer on the lower right of the display will begin counting down.

5.5. At the completion of the counting cycle, record onto Part 3 of the personnel monitoring data sheet (Figure 2) the chest count rate displayed on the E600.

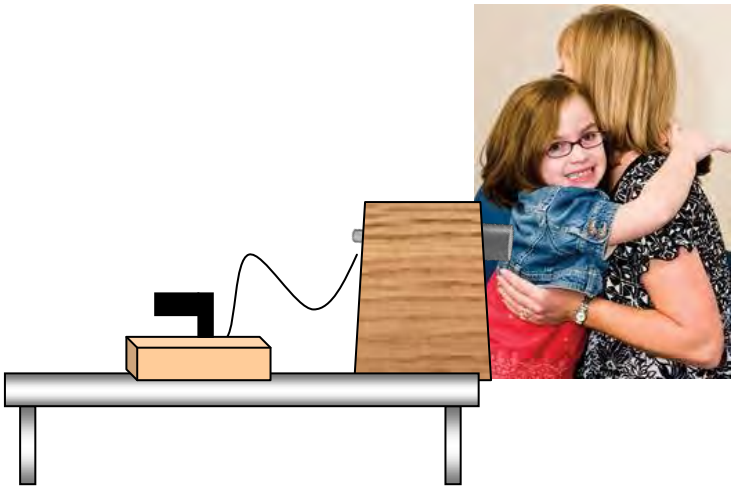
6. PERSONNEL MONITORING – INFANT

6.1. An infant is considered an individual who can be comfortably held on the chest of an adult. See picture below for illustration. All infants should be monitored with their back to the probe.

6.2. Infants will be scanned while being held by a responsible adult. Before scanning an infant, the responsible adult will be scanned following procedure 5 above.

6.3. The responsible adult must be scanned prior to the infant because the CPM results of scanning the responsible adult will be the background value for the infant. A Responsible Adult with a verified <MDA result is required for infant monitoring.

6.4. The responsible adult will hold the infant near the adult's chest as shown below.



Placement of SPA3 Probe on Child with Adult Holding

6.5. Turn/ensure the rotary switch to “Scaler”. Note this may start a counting cycle that can be ignored.

6.6. Set/ensure the E600 to channel 1, 2, or 3 as directed, which have 10, 20, and 30 minute count times respectively. Normal count time is 10 minutes (Channel 1).

6.6.1. This can be accomplished by depressing the “Chnl” key on the E600 handle to cycle through the three channels. Note this may start a counting cycle that can be ignored. Select the appropriate channel by observing the count time on the lower right of the display and stop at the appropriate count time.

6.6.2. Record the count time in the chest section of Part 3 of the personnel monitoring data sheet (Figure 2).

6.6.3. Position the end of the SPA-3 detector in contact with the back such that the centerline of the detector passes through the effective center of the lungs. Note the effective center of the lungs is located approximately one inch above the base of the sternum. Note the base of the sternum is the apex where the rib cage forms an upside down letter “V”; position the end of the SPA-3 detector at the same height but from the back.

6.7. Depress the star key on the E600 to officially start the counting cycle. Note that the timer on the lower right of the display will begin counting down.

6.8. At the completion of the counting cycle, record onto Part 3 of the personnel monitoring data sheet (Figure 2) the chest count rate displayed on the E600.

7. SIGNATURES AND REVIEWS

7.1. The individual performing the monitoring shall print their name on the bottom of the personnel monitoring data sheet (Figure 2).

7.2. The individual monitored shall sign the bottom of the personnel monitoring data sheet (Figure 2).

7.3. The personnel monitoring data sheet shall then be forwarded to an individual authorized to perform the counting review. This individual shall print their name on the bottom of the personnel monitoring data sheet.

7.4. The personnel monitoring data sheet shall be forwarded to an authorized Health Physicist or Radiological Health organization for assessment and review.

FIGURE 1

Instructions: Use one row per series of Chest, Back, Thyroid, and Air Measurements at the beginning and end of each day. The count for the Responsible Adult will provide the infant background. Once background measurements are taken do no move probes as they should be in the same position during internal monitoring of people. Seek to do measurements in places where the lowest background levels are possible and free of high levels of electromagnetic interference. Scan this sheet and post to DOEHS each day along with the E600/SPA-3 datasheets and FastScan/AccuScan printouts if applicable.

E600 Serial Number:							**SPA-3 Serial Number:**		
Date DD MMM YYYY	**Start Time Use 24 Hour clock**	**Location where IM took place. (Ex: CVN-73 Deck X, Atsugi AccuScan Warehouse, etc.)**	**Background Count Rate on Chest of Clean Human Phantom (CPM)**	**Background Count Rate on Back of Clean Human Phantom (CPM)**	**Background Count Rate on Thyroid of Clean Human Phantom (CPM)**	**Background Count Rate on Chest or Back of Responsible Adult (CPM)**	**Background Count Rate Free In Air (CPM)**	**Print Last, First I. of Individual used as the Clean Human Phantom**	**Print Last, First I. of Individual Performing Measurements**

FIGURE 2 INVESTIGATIONAL INTERNAL MONITORING OF US PERSONNEL ASSOCIATED WITH JAPAN NUCLEAR ACCIDENT

Part 1 – Demographics (Print Legibly)

Name (Last, First, MI)						
Soc Sec Num	_ _ _- _ _ -_ _ _ _	Weight (lbs) _____		Height (inches) _____		
Date of Birth		Male	☐	Female	☐	

Military Branch		Sponsors Name (Last, First, MI)	
Address		Sponsors Social Security Number	_ _ _- _ _ -_ _ _ _

Part 2 – Japan Assignment (Print Legibly)

Assigned Location	
Date of First Potential Exposure	
KI Administered? Date started	
Other information: (i.e.- departed Japan 4 Apr, returned 25 May)	

Part 3 – Internal Monitoring (Print Legibly)

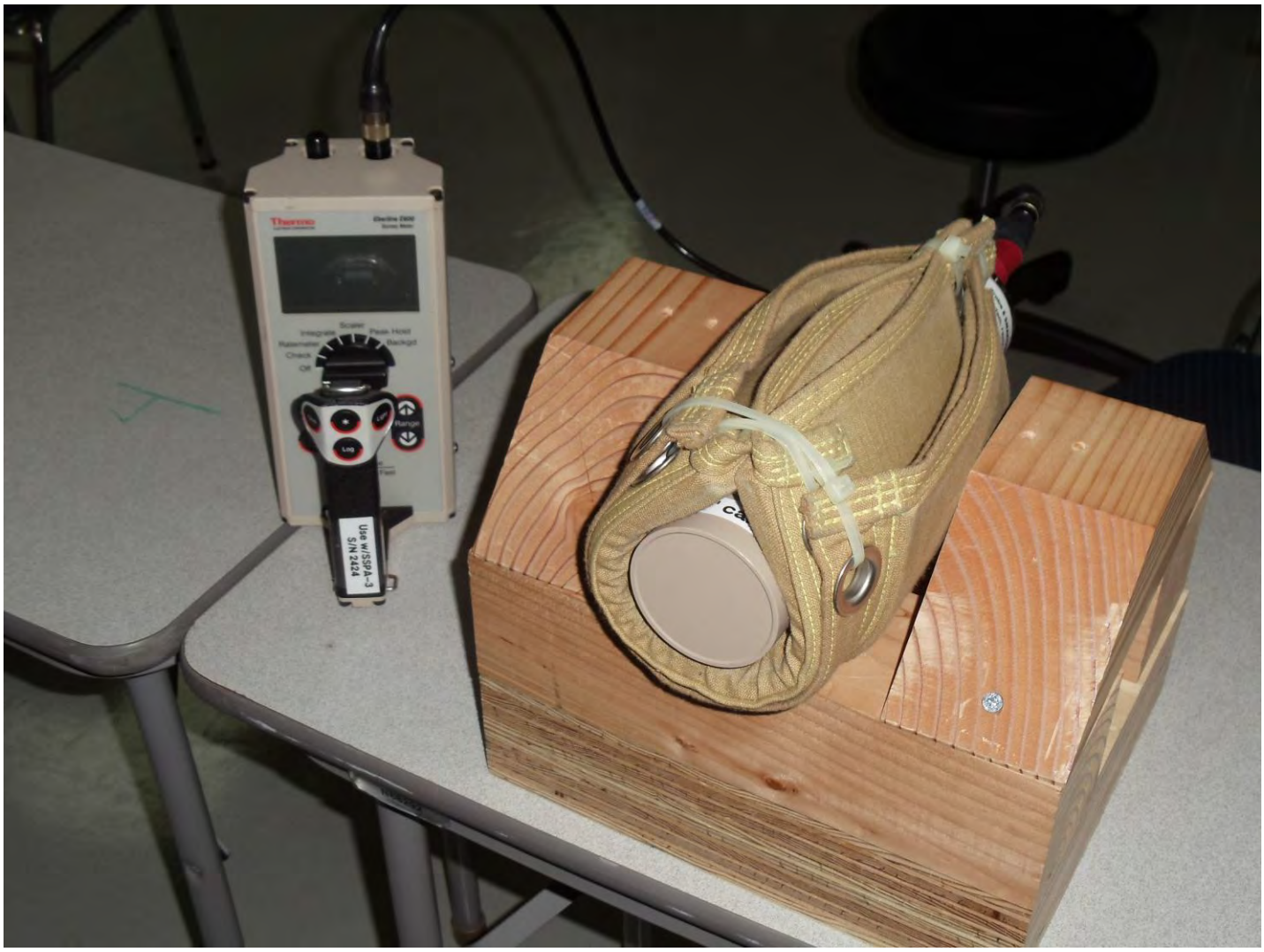
Monitoring System		E600/SPA-3	AccuScan/ FastScan	
Date and Time of Monitoring				
Serial Numbers (E600 / SPA-3)		/		
Spectrum File Name		N/A		
Background Data (CPM)	Date/Time		MDA (I-131)	
	CH* Phantom Chest		MDA (Cs-134)	
	CH Phantom Back		MDA (Cs-137)	
	CH Phantom Thyroid		I-131 Activity (nCi)	
	Responsible Adult (C or B)*			
	Free-in Air			
	* Note: CH is acronym for Clean Human. "C" and "B" refer to chest and back respectively.		Cs-134 Activity (nCi)	
Thyroid Data	Length of Count Time		Cs-137 Activity (nCi)	
	CPM Value			
Chest/Back Data	Length of Count Time		N/A	N/A
	CPM Value			

Counting Performed by (Print Last, First M.): _____

Counting Reviewed by (Print Last, First M.): _____

Signature of Individual Counted: _____

FIGURE 3 E600/SPA-3 set up for Background Measurement and Personnel Monitoring



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Appendix E.

E600/SPA-3 Calibration for Iodine-131

This appendix displays the memorandum to file of the I-131 calibration of the E-600/SPA-3 portable instrument used to perform OT RIMIS measurements.

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10 Apr 11

MEMORANDUM TO FILE

Subj: E600/SSPA3 IODINE-131 CALIBRATION

1. Background.

1.1. The E600 portable digital RADIAC is used with a SPA-3 detector. The SPA-3 is a 2 x 2 inch Sodium Iodide (NaI) gamma scintillation detector.

1.2. The E600/SPA-3 detector can detect the 364 keV (~90%), 637 keV (~7.3%), 722 keV (2.1%), and 163 keV (0.5%) gammas emitted from the decay of I-131.

1.3. The ingestion or inhalation of I-131 will collect (30%) in the thyroid gland with a 2-component retention exponential loss. The effective half-life for I-131 in the thyroid is approximately 7.5 days based on a physical half-life of 8.04 days and a biological half-life of 100 days.

1.4. Calibration of the E600/SPA-3 is required to convert corrected counts per minute (ccpm) to I-131 activity (nCi) retained in the thyroid.

2. Methods and Procedures.

2.1. A calibrated E600/SPA-3 was provided by Knolls Atomic Power Laboratory (KAPL) serial number 03345/2444.

2.2. The SPA-3 probe was connected to the E600 using the 3 ft cable provided by KAPL. Connections were tight. All three channels were calibrated identically to measure energies between 88 keV and 2 MeV.

2.3. The detector was energized and battery indicator verified (88%). The rotary switch was turned to "Scaler" and response time toggle was in the "slow" position. The E600 was in Gross mode as evidence by the absence of the word "Net".

2.4. The detector was energized for 30 minutes prior to recording measurements. The background was approximately 22 kcpm due to the Nuclear Medicine Department operations nearby. In order to reduce the background and to provide the most accurate calibration factor, the SPA-3 probe was shielded with Pb blocks.

2.5. A neck phantom provided by the National Naval Medical Center (NNMC-Bethesda) was utilized to mimic field measurements. The phantom has two cylindrical holes for side-by-side test tube placement that models the 2-lobe thyroid gland.

2.6. In order to calibrate the E600/SPA-3, NNMC-Bethesda provided a small glass test tube containing 5.45 uCi of I-131 in 1.3 ml of water. The activity was measured in a Capintec 15-R dose calibrator and in a NaI well chamber (LTi). This source was too active for on-phantom measurements with the E600 and, therefore, served as a calibration standard for two low-activity sources, which were too low to be accurately measured in the Capintec chamber. These two sources had identical geometry to the calibration source.

2.6.1. NNMC-Bethesda provided two small glass test tubes each filled with 1.3 ml of I-131 solution. Based on the calibration standard, the combined activity of the two test tubes was 84.2 nCi. The two tubes were loaded into the neck phantom.

2.7. The loaded neck phantom was measured for 10 and 30 minutes with the SPA-3 probe placed on the phantom and centered over the source. Since the half-life of I-131 (192 hours) is much greater than the measurement time (~2 hrs), decay correction was not utilized.

2.8. Background measurements were obtained between and after source measurements - 10 and 30-minute samples. The background measurement included the phantom and unfilled test tubes.

3. Results.

3.1. The time-weighted average of the two background measurements was **489 cpm.**

3.2. The table below shows the results of the source measurement and the average calibration factor.

I-131	Source 1
10-min sample (cpm)	16440
10-min sample (ccpm)	15951
30-min sample (cpm)	16440
30-min sample (ccpm)	15951
Activity (nCi)	84.2
Cal Factor 10 min (nCi/ccpm)	0.0053

Cal Factor 30 min (nCi/ccpm)	0.0053
Cal Factor (nCi/ccpm)	**0.0053**

3.3. The average calibration factor for the E600/SPA-3 for I-131 is **0.0053 nCi/ccpm or 189 ccpm/nCi.**

3.4. The Lower Limit of Detection (LLD) in ccpm is determined using the SE700-AA-MAN-100/RADIAC Vol 1 manual. The background count rate determines the LLD. Using the KAPL background count rate of 3930 cpm, the **LLD is approximately 76 cpm.**

3.5. The Minimum Detectable Activity (MDA) is a theoretical calculation based on the conversion factor and LLD. The MDA is 0.4 nCi. However, this MDA does not take into account the uncertainty associated with the calibration standard, activity of test tubes, and the position of the SPA-3 probe at the neck. **The MDA should be quoted as approximately 1 nCi.**

Reed Selwyn, PhD
LCDR MSC

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Appendix F.

Derivation of Cesium Calibration Factors for the E-600/SPA-3

F-1. Introduction

This appendix describes the concept and equations used to derive the Cs-134 and Cs-137 calibration factors (CFs) for the E-600/SPA-3 portable IM scan instrument. The CFs are based on the underlying principle that the effective doses calculated for an individual from measurements on each system are equal to each other. The basis for the CFs is a set of measurements taken on the same individuals with both the fixed and the portable systems. The derivation of CFs for the two isotopes is identical except for the use of isotope-specific radiological and dose coefficient (DC) characteristics, counting data, and intake retention fractions (IRFs). The derivation of the Cs-134 CF is shown below to illustrate the procedure.

F-2. Derivation of Cs-134 Calibration Factor

The basic principle of the cesium CF derivation is that the effective doses calculated for an individual from measurements on the fixed (e.g., ACCUSCAN) and portable (E-600/SPA-3) systems are equal to each other. For this derivation, a set of dual measurements on four individuals was used. The equivalence of the average effective doses from Cs-134 for these four individuals is shown as the initial condition in Equation F-1.

$$\overline{E(\tau)}_{Cs-134\ Fixed} = \overline{E(\tau)}_{Cs-134\ E600} \qquad \text{(F-1)}$$

where:

$\overline{E(\tau)}_{Cs-134\ Fixed}$ = Average effective dose from Cs-134 (n=4) calculated using fixed system scans (rem)

$\overline{E(\tau)}_{Cs-134\ E600}$ = Average effective dose from Cs-134 (n=4) calculated using portable system scans (rem)

The remainder of the CF derivation consists of a series of algebraic substitutions and manipulations, which are described below.

A series of three equations is used to expand and then simplify the right side of Equation F-1. First the details of the average effective dose from Cs-134 calculated using portable system scans are shown Equation F-2. Then, this equation is simplified by substituting an average CF for the individual CF for each measurement, and removing the constants from the summation, as shown in Equation F-3. Note that all four measurements were made on the same post-intake day, so the IRF value is the same for each measurement and is treated here as a constant. A final substitution is then made to obtain Equation F-4.

$$\overline{E(\tau)}_{Cs-134\ E600} = \frac{\sum_{i=1}^{4}\left[\frac{(Gross_{i,\ E600} - Bkg_{i\ E600}) \times PF_{Cs-134} \times CF_{i,Cs-134\ E600} \times DC_{Cs-134}}{IRF_{i,Cs-134}}\right]}{4} \quad \text{(F-2)}$$

$$\overline{E(\tau)}_{Cs-134\ E600} = \overline{CF}_{Cs-134\ E600} \times DC_{Cs-134} \times IRF_{i,Cs-134} \times PF_{Cs-134} \times \frac{\sum_{i=1}^{4}\left[\left(Gross_{i,\ E600} - Bkg_{i\ E600}\right)\right]}{4} \quad \text{(F-3)}$$

$$\overline{E(\tau)}_{Cs-134\ E600} = \overline{CF}_{Cs-134\ E600} \times DC_{Cs-134} \times IRF_{i,Cs-134} \times PF_{Cs-134} \times \overline{Net}_{E600} \quad \text{(F-4)}$$

where:

$Gross_{i,\ E600}$	=	Gross counts per minute from E-600/SPA-3 (cpm)
$Bkg_{i\ E600}$	=	Background counts per minute from E-600/SPA-3 (cpm)
PF_{Cs-134}	=	Photon fraction for Cs-134 (unitless)
$CF_{i,Cs-134\ E600}$	=	Cs-134 calibration factor for a single E-600/SPA-3 measurement (nCi cpm^{-1} or Bq cpm^{-1})
DC_{Cs-134}	=	Dose coefficient for Cs-134 (Sv Bq^{-1} or rem nCi^{-1})
$IRF_{i,Cs-134}$	=	Intake retention fraction for Cs-134 (unitless)
$\overline{CF}_{Cs-134\ E600}$	=	Average Cs-134 calibration factor for E-600/SPA-3 (nCi cpm^{-1} or Bq cpm^{-1})
$\overline{Net}_{E600}$	=	Average net count rate for the E-600/SPA-3 (cpm)

Next, the left side of Equation F-1 is expanded and simplified in a similar manner as shown above for the right side of Equation F-1. This is shown in the following two equations.

$$\overline{E(\tau)}_{Cs-134\ Fixed} = DC_{Cs-134} \times \frac{\sum_{i=1}^{4}\left[\frac{(A_{i,Cs-134})}{IRF_{i,Cs-134}}\right]}{4} \quad \text{(F-5)}$$

$$\overline{E(\tau)}_{Cs-134\ Fixed} = DC_{Cs-134} \times IRF_{i,Cs-134} \times \overline{A}_{Cs-134,Fixed} \quad \text{(F-6)}$$

where:

$A_{i,Cs-134}$ = Cs-134 activity as determined by a single fixed system scan (Bq or nCi)

$\overline{A}_{Cs-134,Fixed}$ = Average Cs-134 activity as determined by multiple fixed system scans (Bq or nCi)

The right sides of Equations F-4 and F-6 are then substituted into Equation F-1, and the new equation is simplified by cancelling like terms on both sides:

$$DC_{Cs-134} \times IRF_{i,Cs-134} \times \overline{A}_{Cs-134,Fixed} = \overline{CF}_{Cs-134\ E600} \times DC_{Cs-134} \times IRF_{i,Cs-134} \times PF_{Cs-134} \times \overline{Net}_{E600} \quad \text{(F-7)}$$

$$\overline{A}_{Cs-134,Fixed} = \overline{CF}_{Cs-134\ E600} \times PF_{Cs-134} \times \overline{Net}_{E600} \quad \text{(F-8)}$$

Finally, Equation F-8 is rearranged to solve for the average Cs-134 CF as:

$$\overline{CF}_{Cs-134\ E600} = \frac{\overline{A}_{Cs-134,Fixed}}{PF_{Cs-134} \times \overline{Net}_{E600}} \quad \text{(F-9)}$$

F-3. Derivation of Cs-137 Calibration Factor

The derivation of the average Cs-137 CF is the same as shown above for Cs-134, except for the use of values for activity, PF, DC, and IRF that are specific to Cs-137. The derived equation for average Cs-137 CF is:

$$\overline{CF}_{Cs-137\ E600} = \frac{\overline{A}_{Cs-137,Fixed}}{PF_{Cs-137} \times \overline{Net}_{E600}} \quad \text{(F-10)}$$

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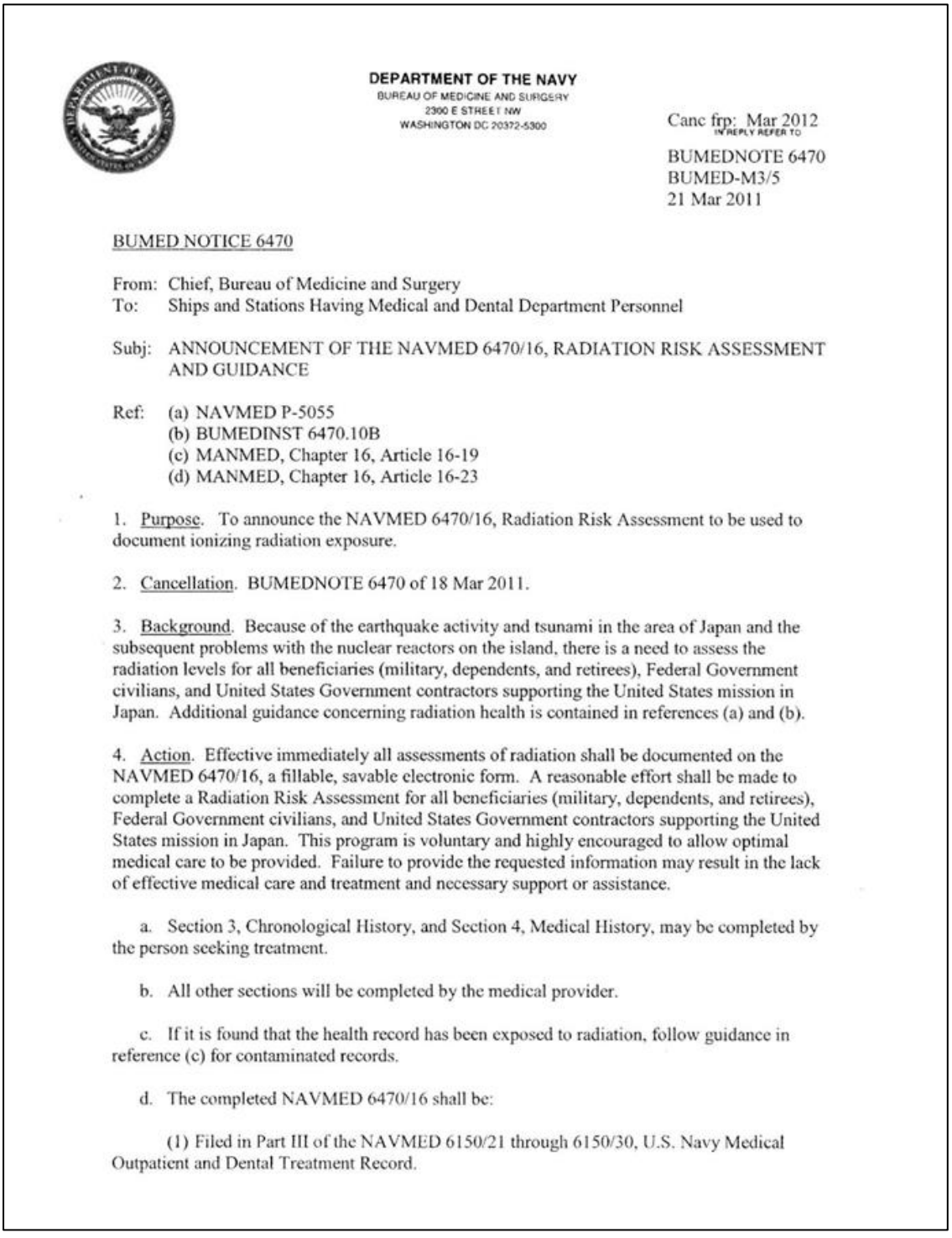
Appendix G.

U.S. Navy Radiation Risk Assessment Guidance

G-1. BUMEDNOTE 6470 of March 21, 2011



DEPARTMENT OF THE NAVY
BUREAU OF MEDICINE AND SURGERY
2300 E STREET NW
WASHINGTON DC 20372-5300

Canc frp: Mar 2012
IN REPLY REFER TO
BUMEDNOTE 6470
BUMED-M3/5
21 Mar 2011

BUMED NOTICE 6470

From: Chief, Bureau of Medicine and Surgery
To: Ships and Stations Having Medical and Dental Department Personnel

Subj: ANNOUNCEMENT OF THE NAVMED 6470/16, RADIATION RISK ASSESSMENT AND GUIDANCE

Ref: (a) NAVMED P-5055
(b) BUMEDINST 6470.10B
(c) MANMED, Chapter 16, Article 16-19
(d) MANMED, Chapter 16, Article 16-23

1. Purpose. To announce the NAVMED 6470/16, Radiation Risk Assessment to be used to document ionizing radiation exposure.

2. Cancellation. BUMEDNOTE 6470 of 18 Mar 2011.

3. Background. Because of the earthquake activity and tsunami in the area of Japan and the subsequent problems with the nuclear reactors on the island, there is a need to assess the radiation levels for all beneficiaries (military, dependents, and retirees), Federal Government civilians, and United States Government contractors supporting the United States mission in Japan. Additional guidance concerning radiation health is contained in references (a) and (b).

4. Action. Effective immediately all assessments of radiation shall be documented on the NAVMED 6470/16, a fillable, savable electronic form. A reasonable effort shall be made to complete a Radiation Risk Assessment for all beneficiaries (military, dependents, and retirees), Federal Government civilians, and United States Government contractors supporting the United States mission in Japan. This program is voluntary and highly encouraged to allow optimal medical care to be provided. Failure to provide the requested information may result in the lack of effective medical care and treatment and necessary support or assistance.

a. Section 3, Chronological History, and Section 4, Medical History, may be completed by the person seeking treatment.

b. All other sections will be completed by the medical provider.

c. If it is found that the health record has been exposed to radiation, follow guidance in reference (c) for contaminated records.

d. The completed NAVMED 6470/16 shall be:

(1) Filed in Part III of the NAVMED 6150/21 through 6150/30, U.S. Navy Medical Outpatient and Dental Treatment Record.

(2) A copy shall be forwarded under a cover letter to the Officer in Charge, Navy Dosimetry Center, 8901 Wisconsin Avenue, Bldg 4/6, Bethesda, MD 20889-5614. The cover letter shall include a point of contact, phone number, and e-mail address.

(3) Activities that submit completed NAVMED 6470/16 shall maintain a copy of the form and accountability for the number of assessments completed.

5. Forms. The following forms are available at https://navalforms.daps.dla.mil.

a. NAVMED 6470/16 (3-2011), Radiation Risk Assessment.

b. NAVMED 6150/21 through 6150/30 (Rev. 11-96), U.S. Navy Medical Outpatient and Dental Treatment Record.

6. Cancellation Contingency. Retain until incorporated into references (a) and (d).

A. M. Robinson, Jr.

A.M. ROBINSON, JR.

Distribution is electronic only via the Navy Medicine Web Site at:
http://www.med.navy.mil/directives/Pages/default.aspx

RADIATION SCREENING AND RISK ASSESSMENT

PRIVACY ACT STATEMENT

Authority: 10 U.S.C. 136, Under Secretary of Defense for Personnel and Readiness; 10 U.S.C. 1071 (NOTE), Annual Beneficiary Survey; 10 U.S.C. Chapter 55, Medical and Dental Care; 42 U.S.C. 11131-11152, Health Care Improvement Act of 1986; 32 C.F.R. 199.17, TRICARE program; 45 C.F.R. Parts 160 and 164, General Administrative Requirements and Security and Privacy; DoDD 3216.2, Protection of Human Subjects and Adherence to Ethical Standards in DoD-Supported Research; DoDD 6025.13, Medical Quality Assurance (MQA) in the Military Health System (MHS); and E.O. 9397 (SSN), as amended.

Purpose: To collect, assemble, interpret, analyze, report and publish surveys; research, study, statistical and informational data, in order to improve the quality of DoD health care and the health status, welfare and well-being of the DoD beneficiary population. Uses of identifiable data include primary analysis; secondary analysis; non-response analysis; and cross-mapping analysis. Results will only be reported in the aggregate.

Routine uses: In addition to those disclosures generally permitted under 5 U.S.C. 552a(b) of the Privacy Act of 1974, these records may specifically be disclosed outside the DoD as a routine use pursuant to 5 U.S.C. 552a(b)(3) as follows: To the Department of Health and Human Services and/or the Department of Veterans Affairs consistent with their statutory administrative responsibilities pursuant to 10 U.S.C. Chapter 55, Medical and Dental Care, and 38 U.S.C 613, Judiciary and Judicial Procedure. To the Office of Personnel Management for purposes related to DoD Federal employees and/or their health care benefits in DoD. The Department frequently contracts with a private firm for the purpose of conducting surveys or studies and in collecting, analyzing, aggregating, otherwise refining, or evaluating data in this system. Relevant records are disclosed to such contractors. Contractors must maintain Privacy Act of 1974, Health Insurance Portability and Accountability Act of 1996 Privacy and Security Rule training, and observe all required and related safeguards with respect to such records as required by DoD 5400.11-R, Department of Defense Privacy Program, and DoD 6025.18-R, Department of Defense Health Information Privacy Regulation. To State Departments of Health for health care delivery programs, where such programs effect benefits determinations between these Department-level programs, continuity of clinical care, or effect payment for care between Departmental programs inclusive of care provided by commercial entities under contract to these three Departments. To Academia, non profit and commercial entities, for surveys or research, where such releases are consistent with the mission of the Military Health System and where exchange and coordination of information and data are consistent with the Privacy Act of 1974, the Heath Insurance Portability and Accountability Act of 1996 Privacy and Security Rules, and applicable DoD Information Security regulations. The DoD Blanket Routine Uses set forth at the beginning of the Office of the Secretary of Defense compilation of systems of records notices apply to this system with the following noted exceptions: NOTE: This system of records contains individually identifiable health information. The DoD Health Information Privacy Regulation, DoD 6025.18-R issued pursuant to the Health Insurance Portability and Accountability Act of 1996, applies to most health information. DoD 6025.18-R may place additional procedural requirements on the uses and disclosures of such information beyond those found in the Privacy Act of 1974 or mentioned in this system of records notice.

Disclosure: Voluntary. However, failure to provide requested information may result in lack of effective medical care/treatment and necessary support/assistance.

1. RADIATION RISK STATEMENT

This form is to document full disclosure of environmental exposures and possible health effects for all personnel and their families who were assigned as permanent or on a temporary assignment in areas from central to northern Japan during the period From 11 March 2011 To _____ (End Date).

RADIATION RISK STATEMENT: Although exposure to ionizing radiation is associated with some degree of risk, epidemiological studies have not demonstrated adverse health effects in individuals exposed to small doses. At doses below 0.05 Sv (5 rem), negative health effects are not observed.

A. Issued Purpose ☐ Decontamination ☐ Symptomatic ☐ Requested/Required

B. Thermoluminescent Device (TLD) Issued During Event ☐ Yes ☐ No Date Issued: _____ Issued by _____

2. DEMOGRAPHIC INFORMATION

A. Check One ☐ Active Duty ☐ Family Member/Dependent ☐ DoD Civilian/Contractor ☐ Retiree ☐ Other _____

B. Occupation

C. Duty Station	D. Home Address in area of Duty Station

3. CHRONOLOGICAL HISTORY

A. List duties during event (e.g., firefighter, search and rescue, flight crew, decontamination team.)

B. For each day in Japan since March 2011, list location (city), primary duties, and whether if you were primarily inside or outside a building. (e.g., Mar 12: Yokosuka, Naval Hospital, inside)

PATIENT'S IDENTIFICATION: *(For typed or written entries, give: Name - last, first, middle; SSN; FMP; Sex; Date of Birth; Rank/Grade.)*

HOSPITAL OR MEDICAL FACILITY	STATUS
DEPARTMENT / SERVICE	RECORDS MAINTAINED AT
SPONSOR'S NAME	SSN
RELATIONSHIP TO SPONSOR	

C. List non-routine events location, day/time, and duration (Example: emergency response (3 hr), Search and rescue (3 hr), provide aid (4 hr)):

4. MEDICAL HISTORY

A. Current Medications (list all)

B. Potassium Iodine (KI) doses	☐ Yes	☐ No	Number of Doses: _____
Source of KI (Example: Yokosuka Clinic, Ship, other):			
C. Previous Decontamination	☐ Yes	☐ No	If Yes, when and where?
D. History of Major Illness or Injury	☐ Yes	☐ No	
E. History of Hospitalization or surgery	☐ Yes	☐ No	
F. History of Cancer	☐ Yes	☐ No	If Yes, list type(s):
G. Do you Smoke?	☐ Yes	☐ No	If Yes, packs/day
H. Do you have Allergies	☐ Yes	☐ No	If Yes, what allergies
I. Are you pregnant	☐ Yes	☐ No	☐ NA
J. Breast Feeding?	☐ Yes	☐ No	☐ NA
K. Blood Disorders (i.e., Anemia)	☐ Yes	☐ No	If Yes, list type(s):
L. Other (List)			

PATIENT'S IDENTIFICATION: *(For typed or written entries, give: Name - last, first, middle; SSN; FMP; Sex; Date of Birth; Rank/Grade.)*

HOSPITAL OR MEDICAL FACILITY	STATUS
DEPARTMENT / SERVICE	RECORDS MAINTAINED AT
SPONSOR'S NAME	SSN
RELATIONSHIP TO SPONSOR	

M. History of Exposure to Ionizing Radiation

☐ No know previous exposure ☐ If previously exposed, current lifetime exposure: _____ (mrem) ☐ Previously exposed, unknown lifetime exposure

☐ Previous Radiation Screening and Risk Assessment completed: ☐ Yes ☐ No If Yes, Dates _____

N. Do you have any concerns regarding your exposure during this period in Japan (please list)?

5. ACKNOWLEDGEMENT OF HEALTH CONSULTATION AND COUNSELING

I understand today's health consultation and was provided information or where to find additional information regarding ionizing radiation exposure.

A. PRINTED NAME	B. SIGNATURE	C. DATE

6. PROVIDER

A. COMMENTS

☐ No Comments ☐ Further evaluation recommended: medical examiner must comment if checked

B. NOTES

C. PROVIDER'S NAME	D. PROVIDER'S SIGNATURE	E. DATE

PATIENT'S IDENTIFICATION: *(For typed or written entries, give: Name - last, first, middle; SSN; FMP; Sex; Date of Birth; Rank/Grade.)*

HOSPITAL OR MEDICAL FACILITY	STATUS
DEPARTMENT / SERVICE	RECORDS MAINTAINED AT
SPONSOR'S NAME	SSN
RELATIONSHIP TO SPONSOR	

INSTRUCTIONS:

1) Radiation Risk Statement
End Date: Enter date you exited affected areas in risk Statement
A. Purpose: Check one block indicating why this form is being completed as directed below:
Decontamination: as a result of a Decontamination procedure,
Symptomatic: Member is being treated for symptoms related to radiation exposure health issues
Requested/Required: Member requests a screening or is enroute or at terminal exit point leaving Japan.
B. TLD Issued During Event: indicate by circling YES of NO that a Thermoluminescent Device (TLD) was issue to the person identified on this form
Date issue. Write the date (DDMMMYYYY) the TLD was issued and by what entity (command)

2) Demographic Information
A) Check box indicating status:
Active Duty – All members of the Armed forces
DOD Civilian / Contractor - Federal employees or Contractors hired by Department of Defense
Dependents / Retirees - Family members and Retired service members and their family
B) Occupation: What is your job title or what do you do on your job?
C) Duty Station: What is the name of the place you or the active duty member is assigned?
D) Home Address in area of Duty Station: write address of the house you are currently living at you duty Station.

3) Chronological History
1. Duties during event: What duties did you perform as a result of the event in Japan? Example is Firefighter, Worked as a Search and Rescue Crew Member performing rescue operations over Atsugi. List multiple duties if performed multiple functions.
2. For each day in Japan since March 2011, list location (city), primary duties, and whether if you were primarily inside or outside a building.
What cities did you perform your duties and what function you were performing there. Indicate whether you routinely worked inside the building or outside the building. (e.g., Mar 12: Yokosuka, Naval Hospital, inside).
3. List non-routine events location, day/time, and duration
List tasks or event that you performed that were occasionally performed and the time spent performing these tasks. (Example: emergency response (3 hr), Search and rescue (3 hr), provide aid (4 hr), Trip to the grocery store (30 min).

4) Medical History
A. Current Medications (list all): List of medication you currently are taking.
B. Potassium Iodide (KI) doses: indicate if you have been taken Potassium Iodine during this event.
-Number of doses: How many times or how long have you been taken this medication?
-Source of KI (Example: Yokosuka clinic, ship, other): Where did you get this medication?
C. Previous Decontamination (circle one): Indicate if you have had a decontamination procedure performed on you (other than frisking).If yes is answered, list where and dates(s) procedure was conducted.
Items D - L.: Indicate appropriate response for each line indicating if you have or had a history of each line item. If a yes response is answered (as applicable), briefly explain.
M. History of Exposure to Ionizing Radiation: Check appropriate box indicating if you have had previous exposure to Ionizing Radiation. If there was a previous exposure list Current lifetime Dose as appropriate.
N. Do you have any concerns regarding your exposure during this period in Japan (please list)? List concerns from this event.

5) ACKNOWLEDGMENT OF HEALTH CONSULTATION AND COUNSELING
Print your full name, Sign and date stating your understanding of this health assessment screening form.

6) PROVIDER
A) Comments- Check appropriate box indicating whether comments or further recommendations are required.
B) Notes- List comments or further recommendations deemed appropriate as a result of this screening of examination.

G-2. ASD(HA) Introduction to Dr. Woodson's Guidance Memo (May 2, 2011)

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE
HEALTH AFFAIRS
SKYLINE FIVE, SUITE 810, 5111 LEESBURG PIKE
FALLS CHURCH, VIRGINIA 22041-3206

TRICARE MANAGEMENT ACTIVITY

MAY 2 2011

MEMORANDUM FOR CHIEF MEDICAL OFFICER, TRICARE REGIONAL OFFICE–NORTH
CHIEF MEDICAL OFFICER, TRICARE REGIONAL OFFICE–SOUTH
CHIEF MEDICAL OFFICER, TRICARE REGIONAL OFFICE–WEST
TRI WEST HEALTHCARE ALLIANCE CONTRACTING OFFICER
HEALTH NET FEDERAL SERVICES CONTRACTING OFFICER
HUMANA MILITARY HEALTHCARE SERVICES CONTRACTING OFFICER

SUBJECT: Introduction to Dr. Jonathan Woodson's Guidance Memo

Thank you for helping us deliver world-class health care to those who protect and defend our freedom. The purpose of this letter is to address some questions that civilian/private sector clinicians may be faced with when patients present to them with concerns about potential radiation exposure as a result of the March 11, 2011, earthquake and tsunami impacting Japan.

Please be reassured that to date, none of the radiation screenings of our personnel or their families returning from Japan have indicated radiation exposures that would pose a risk for acute or long-term health effects. Nonetheless, some of these families may seek medical advice to address concerns regarding their potential exposure to radiation or to ask about any increased risk of illness. The attached guidance from the Assistant Secretary of Defense (Health Affairs) directs clinicians to resources that include the latest information on radiation exposure from the Centers for Disease Control and Prevention, Food and Drug Administration, the State Department, and the Environmental Protection Agency and is provided to assist with concerns that may arise.

Some patients may seek care in the civilian sector. It is very unlikely that there has been any medically significant exposure for anyone outside of a 50-mile radius of the Fukushima Daiichi power plants. If you are concerned, however, based on the clinical manifestations and the patient's history that a particular beneficiary is in need of further medical testing and treatment, the following International Classification of Diseases (ICD) codes may be useful:

1. Effects of radiation, Unspecified (ICD-990)
2. Exposure to radiation (ICD-E926)
3. Exposure to unspecified radiation (ICD-E926.9)

4. Person with feared complaint in whom no diagnosis was made (V65.5)
5. Observation for other specified suspected conditions (ICD-V71.89)

In addition to potential episodic health care visits, Service members, Department of Defense civilians, military contractors, and their families are being tracked in a database in order to identify any potential long-term effects, as unlikely as these are believed to be. A Web site for support to our beneficiaries returning from Japan has been established at: http://www.tricare.mil/tsunami/default.aspx.

Thank you for your interest in the Military Health System and its beneficiaries. We at TRICARE are proud to serve our Nation's military heroes and their families and are committed to providing them the best possible health care.

C. S. Hunter
RADM, MC, USN
Deputy Director

Attachment:
As stated

cc:
Ms. Angie Figueroa, TMA

Guidance to Health Care Providers:

Military and other Government personnel returning from Japan may seek appointments at your offices or Military Treatment Facilities to ask for medical evaluations for their recent radiation exposures and to ask whether any exposure to radiation might pose health risks to themselves or others in their family. Radiation levels are being recorded at all of our military installations in Japan; these measurements are being used to estimate maximum possible exposures for the personnel residing on or near those installations.

At this time, there are no indications that any of our personnel in the vicinity of U.S. military installations in Japan have experienced radiation exposures that would pose a risk for acute or long-term health effects. Returning individuals may, however, have perceptions that they have experienced significant exposure to radiation or that they may be at increased risk of illness. These concerns and perceptions should be addressed, and factual information should be provided to permit patients to understand the nature of the events they have experienced and their impact on current and future health.

When beneficiaries, who recently returned from Japan, present in your clinics, you should:

(1) Be attentive, compassionate, and understanding; actively listen to them—seek any clarifications necessary to ensure you fully understand what those concerns are. Listen to any presenting complaints that may require diagnosis or treatment so that you can clearly understand them and can respond to them appropriately—clinically and through appropriate risk communication.

(2) Some patients may have completed and brought with them a NAVMED 6470, a Radiation Screening and Risk Assessment Form distributed by the Navy. If so, review and ask clarifying questions, complete the form, provide any additional medical follow-up as may be required, and place a copy in the patient's medical record.

In responding to patients' concerns about the possibility of radiation exposure, you may find the following information useful for risk communication.

- Acknowledge the concerns that led the patient to make an appointment and that the possibility of an exposure to radiation should not be taken lightly.
- Each of the Military Services has been diligently monitoring radiation at all of the U.S. Military installations in Japan—to include the air, water, and food.
- As of March 30, 2011, there have been no measured levels of radiation that would result in any radiation-related health problems that might show themselves now or years in the future.
- Although there may be a link between radiation exposure and an increased risk of cancer, especially at high levels of radiation exposure in one episode or with cumulative radiation exposures over years, radiation monitoring results at U.S. military bases in Japan, as of this date, have shown only very small amounts of

radiation related to the event, and negligible radiation exposure for individuals living and working outside of a 50-mile radius from the Fukishima power plant (only a small fraction of the radiation that might be experienced from a diagnostic x-ray or procedure).

- U.S. experts are continuing to monitor the air, water, and food in Japan and will review data collected to ensure that accurate information about levels of radiation exposure continue to be available to inform questions about exposure levels and health risks.

Try to respond to all questions the patient may have. Anxiety may, of course, provoke physical symptoms or aggravate existing clinical conditions, and patients may experience illnesses unrelated to their recent experiences and travel. Provide any clinically indicated evaluations and treatment appropriate to presenting symptoms and medical conditions. There are no biological markers or diagnostic tests to detect exposure to these very low levels of radiation, so diagnostic tests related solely to concerns for radiation exposure are not indicated. Passengers have been screened for contamination both upon exit from Japan and entrance into the United States. Any necessary decontamination measures will have been addressed at these points of embarkation and debarkation.

Patients may have been issued potassium iodide (KI), but have not been advised to take it. If they did take KI, document the number of tablets taken and duration of dosing. Document any side effects of medication (most commonly constipation, nausea, vomiting, stomachache, diarrhea, metallic taste in the mouth, fever, headache, acne, or rarely, more serious conditions such as thyroid storm). There is no indication at this time for use of KI for someone who has returned to the United States from Japan.

Additional sources of information provided by U.S. Government agencies are contained in attachment 1, should be reviewed, and will be updated as circumstances change.

Thank you for your attention and diligence in dealing with this event and supporting our Servicemen and women, their families and others who have returned to the United States in the wake of this event.

Jonathan Woodson, M.D.

Attachment 1

Available Information Resources

The Centers for Disease Control and Prevention's (CDC) Web site includes information on medical management, treatment guidelines, and recommendations that include, but are not limited to, decontamination, acute radiation exposure and acute radiation exposure syndrome, internal contamination, cutaneous radiation injury, countermeasures, and prenatal radiation exposure. The CDC Web site has several training modules for clinicians seeking further information regarding this topic. Additional information can be obtained by signing up to receive electronic mail updates from the CDC. For clinicians and the public who have further questions not addressed by the resources found online, CDC representatives are available 24 hours a day by calling the toll-free number (800) CDC-INFO (800-232-4636). The CDC Web site is: http://emergency.cdc.gov/radiation

The U.S. Department of State and its embassy in Japan is providing information for U.S. citizens concerning all aspects of travel and living in Japan. http://www.state.gov

The Food and Drug Administration's (FDA) Web site also includes information on radiation safety, which addresses topics, such as food safety and medical products. The Web site addresses topics, such as what steps the FDA is taking to ensure the safety of food imported from Japan, about which patients might be concerned. In addition, the FDA Web site also addresses questions that clinicians may have pertaining to medical products that are FDA approved for the treatment of internal contamination with radioactive iodine, and the available supply of pharmacological countermeasures, such as potassium iodine. The Web site is: http://www.fda.gov/newsevents/publichealthfocus/ucm247403.htm

The Environmental Protection Agency (EPA) is committed to protecting and preserving our country's environment. It is monitoring the situation in Japan and is keeping the American people informed. An up-to-date posting of radiation levels from EPA air monitors can be found anytime at: http://epa.gov/japan2011.

TRICARE is providing updated information about this event. Links to sources of additional assistance for TRICARE beneficiaries will be provided on a regular basis at http://www.tricare.mil/tsunami/default.aspx.

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Appendix H.

BUMEDNOTE Announcing NAVMED 6470/17

H-1. BUMEDNOTE 6470 of March 25, 2011

DEPARTMENT OF THE NAVY
BUREAU OF MEDICINE AND SURGERY
2300 E STREET NW
WASHINGTON DC 20372-5300

Canc. frp: Mar 2012

IN REPLY REFER TO
BUMEDNOTE 6470
BUMED-M3/5
25 Mar 2011

From: Chief, Bureau of Medicine and Surgery
To: Ships and Stations Having Medical and Dental Department Personnel

Subj: ANNOUNCEMENT OF THE NAVMED 6470/17, DOSIMETRY ISSUANCE REPORT FOR OPERATION TOMODACHI

Ref: (a) NAVMED P-5055 of Feb 2011
(b) BUMEDINST 6470.10B

1. Purpose. To announce the NAVMED 6470/17, Dosimetry Issuance Report for Operation Tomodachi. NAVMED 6470/17 shall be used to document the distribution of personal thermoluminescent devices.

2. Background. Because of the earthquake activity and tsunami in the area of Japan and the subsequent problems with the nuclear reactors on the island, there is a need to assess the radiation levels for all beneficiaries (military, dependents, and retirees), Department of the Navy civilians employees and contractors supporting the United States mission in Japan. Additional guidance concerning radiation health is contained in references (a) and (b).

3. Action. Effective immediately the issuance of DT-702 Personal Thermoluminescent Devices (TLD) in conjunction with Operation Tomodachi shall be recorded on NAVMED 6470/17, a fillable, savable electronic form.

a. The Field Unit Representative shall:

(1) Have each member complete a DD Form 2005, Privacy Act Statement – Heath Care Records.

(2) Complete NAVMED 6470/14: Section 1, Activity Submitting Report; Section 2, Field Unit Representative; Section 3, Field Representative Telephone and E-mail; Section 4, UIC/RUC; Section 6, Member's Information; and Section 8, Monitoring Period.

b. The Operation Tomodachi Medical Facilities Manager shall complete all other sections of the NAVMED 6470/17.

c. The completed NAVMED 6470/17 shall used to enter data into the Shipboard Non-tactical Automated Data Processing (SNAP) Automated Medical System (SAMS) and create the NAVMED 6470/3, Radiation Exposure Report (Whole Body).

d. A copy of NAVMED 6470/17 and the original NAVMED 6470/3 shall be forwarded under a cover letter to the Officer in Charge, Navy Dosimetry Center, 8901 Wisconsin Avenue, Bldg 4/6, Bethesda, MD 20889-5614. The cover letter shall include a point of contact, phone number, and e-mail address.

e. Activities that submit completed NAVMED 6470/3 and NAVMED 6470/17 shall maintain the original NAVMED 6470/17, a copy of NAVMED 6470/3, the original DD Form 2005, and accountability for the number of TLDs issued.

4. Forms

a. DD Form 2005 (FEB 2005), Privacy Act Statement – Health Records is available electronically at: http://www.dtic.mil/whs/directives/infomgt/forms/eforms/dd2005.pdf.

b. The following NAVMED forms are available electronically at: https://navalforms.daps.dla.mil/web/public/home.

(1) NAVMED 6470/3 (4-2010), Radiation Exposure Report (Whole Body).

(2) NAVMED 6470/17 (3-2011), Dosimetry Issuance Report for Operation Tomodachi.

5. Cancellation Contingency. Retain until incorporated into references (a) and (b).

A. M. Robinson, Jr.

A.M. ROBINSON, JR.

Distribution is electronic only via the Navy Medicine Web Site at: https://www.med.navy.mil/directives/Pages/BUMEDNotes.aspx

Appendix I.

Questions and Answers, Internal Monitoring (USPACOM June 16, 2011)

I-1. Long-Term Effects

Q. What are the long term effects of radiation exposure from the Fukushima Daiichi plant?

A. Radiation and radioactivity levels measured from the release at the Fukushima Daiichi plant varied depending on location. However, the highest levels and concentrations at locations where DoD personnel were present were relatively low and the resulting levels of exposure are unlikely to have any adverse health effects.

Q. At what level of internal contamination would the patient see adverse health effects?

A. We have not screened anyone with contamination levels approaching levels of concern. The long term risks of health effects associated with radiation doses below 6,000 millirem based on study of humans are too small to be observed (UNSCEAR 2000). The highest estimated effective dose to date is 25 millirem.

Q. What are the long term effects on people with immune deficiencies?

A. Radiation exposure at the levels we have seen does not have an effect on the immune system.

Q. There still is not enough information for pregnant women. Who can tell us the impact it will have on pregnancies?

A. The very low levels of exposure to U.S. citizens as a result of this event would have no impact on pregnancies. A physician or medical treatment provider should be able to discuss any potential impacts on pregnancy. For additional information you can find information about radiation and pregnancy on the CDC webpage. http://www.bt.cdc.gov/radiation/

Q. What effect would internal contamination have on a nursing mother and child?

A. The radioactivity we have seen does not indicate any significant level of internal contamination and no health effects are expected. If you have additional concerns, about nursing your child, we recommend they should be discussed with your health care provider.

Q. How soon will I get cancer?

A. Exposure to low levels of radiation or radioactivity does not mean you will get cancer. There are many causes of cancer, both environmental and genetic. Radiation, specifically radiation at these low levels, is a negligible contributor to an overall cancer risk. Cancer concerns should be discussed with a health care provider.

Q. If I get cancer how soon will I die?

A. There are many causes of cancer, both environmental and genetic. Radiation, and specifically radiation at these levels, is a negligible contributor to your overall cancer risk. We recommend you discuss this concern with your health care provider.

Q. Can your equipment detect cancer?

A. No. It detects radiation.

Q. What are the acceptable/safe levels of internal contamination for children, adults, and senior citizens?

A. The National Council on Radiation Protection and Measurement (NCRP) and several Federal agencies recommend that annual effective doses be maintained below 100 millirem or 1 mSv above background radiation levels for all members of the public. The highest estimated doses for DoD emergency response personnel, who have been monitored to date and operated in affected area, are below this level.

Q. How does my exposure compare to other risks, such as background radiation?

A. See script for health physicists conducting monitoring. In general

- If monitoring results are below the minimum detectable levels, we did not detect any internally deposited radioactivity so any potential exposure would be negligible.
- If monitoring result is positive (but less than 100 nanocuries each of cesium 134 & 137, which is below maximum level detected for any individual), your radiation exposure is less than an individual in Denver receives annually from natural background radiation (500 millirem).

Source	Radiation Dose (Effective Dose)
One X-ray (chest)	0.10 mSv (0.010 rem)
One Transcontinental Flight	0.02 mSv (0.002 rem)
Natural Radioactivity (body)	0.30 mSv y^{-1} (0.030 (rem y^{-1})
Cosmic Radiation (space)	0.40 mSv y^{-1} (0.040 (rem y^{-1})

NCRP Report 160 (NCRP, 2009)

I-2. Internal Monitoring

Q. What is Internal Monitoring?

A. Internal radiation monitoring is a screening tool used to measure the amount of radioactivity that may be inside a person's body. It is a non-invasive procedure using sensitive equipment positioned a short distance from the body that can detect very small quantities of radiation emitted by internally deposited radioactivity. We started internal monitoring with those U.S. personnel identified to have had the greatest chance of radiation exposure from the Fukushima Daiichi power plant, generally those who worked within 100 miles of the plant. We are now

offering the opportunity for all other personnel to participate in the monitoring process if they choose.

Q. What were the results of the internal radiation monitoring for those who worked relatively near the Fukushima Daiichi power plant?

A. Over 7000 U.S personnel who worked near the power plants or who wereconsidered to have the greatest opportunity for exposures have been monitored for internal radiation and none of them had levels of internal radioactive contamination of medical concern.

Q. If you are saying that there was no meaningful exposure, why are you offering testing?

A. This screening is an opportunity to confirm that you have received little or no internally deposited radioactivity as a result of the Fukushima Daiichi release. To serve our DOD family, we are providing the opportunity for internal monitoring to any DOD affiliated person who wishes to receive it.

Q. I hear there are military persons being monitored for radiation, is that available for everyone?

A. Internal monitoring is now available to DOD affiliated personnel who were in the affected prefectures. This includes service members, DOD civilians, contractors, retirees and family members.

Q. Can children be scanned for radiation too?

A. Yes, as long as they are DOD beneficiaries and are able to remain still for approximately 20 minutes.

Q. Who needs internal monitoring?

A. Those personnel identified to have had the greatest chance of internally deposited radioactivity due to the Fukushima Daiichi release have been contacted. There are no additional internal monitoring recommendations for personnel that have not already been identified. No other personnel require internal monitoring; however, we want to make the monitoring available to everyone. To serve our DOD family, we are now providing the opportunity for internal monitoring to any DOD affiliated person who wishes to receive it. Anyone who is a DOD beneficiary or employee and can remain still for approximately 20 minutes may be monitored.

Q. Shouldn’t everyone be internally monitored?

A. Based on the very low levels of radiation detected at our military installations, which have been further validated by the internal monitoring data that has been conducted to date, widespread screening is not necessary. There is no requirement or recommendation that everyone be monitored, however, this opportunity is being provided to the DOD family on a voluntary basis.

Q. Can my other family members (in-laws, cousins, uncles, aunts, etc) be screened?

A. At this time, we have the opportunity for screening of DOD beneficiaries. Anyone else would be recommended to consult their personal health care provider if they have concerns.

Q. What if someone is spreading radiation to everyone but doesn't get tested?

A. Internal contamination is contained in the body so it is very difficult to spread from person to person. Upon review of the results so far, it is extremely unlikely that any DOD affiliated person was exposed to any levels of radiation or radioactivity that are of concern, and we are confident that all DOD affiliated personnel have been and continue to remain safe. We are offering voluntary internal monitoring to DOD personnel. To serve our DOD family we want to provide the opportunity for internal monitoring to any DOD affiliated person who chooses to receive it.

Q. Do my children need to be tested?

A. Monitoring is not recommended or required for DOD affiliated personnel, but is being offered on a voluntary basis, and it is your decision if you choose to have your children monitored. To serve our DOD family, we want to provide the opportunity for internal monitoring to any DOD affiliated person who chooses to receive it.

Q. Can I have my pets screened?

A. We are not screening pets. If you have questions about your family pet, we recommend discussing them with a veterinarian.

Q. What do I do if I want to be monitored?

A. Contact xxx at xxx.

Q. If you wait this long to do internal monitoring is it still going to find radiation that might have been there last month?

A. Yes the equipment is sensitive enough to still detect very low levels of radioactivity.

Q. The accident happened over a month ago. How come I wasn't offered screening earlier?

A. The internal monitoring procedure established a priority for those individuals with the highest probability of exposure to radiation; this included responders in controlled zones around the reactor site and personnel conducting decontamination.

Q. Isn't it too late to be tested? There hasn't been any radiation released from the power plant for over a month, and the half life of iodine is only eight days.

A. This screening is still effective because there are other radioactive elements (i.e., cesium) with longer half lives that the equipment can detect at very low levels.

Q. How does the equipment work?

A. Radiation emitted from the body interacts with internal components of the equipment. It detects radiation like a Geiger counter.

Q. What is the chance that the test will say that I was not exposed, when I really was exposed?false negative

A. The monitoring procedure detects any significant amount of radioactivity in your body. The scan is also sensitive enough to measure any the natural background radioactivity in your body, and there is lower limit for detection based on background radiation. However, the sensitivity of the equipment and detailed monitoring procedures ensure any significant amount of radioactivity is detected.

Q. What is the chance that the test will say that I was exposed, when I really wasn't (i.e., false positive)?

A. There is less than a 2% chance that the scan will produce a false positive result. If the scan indicates that there was additional exposure we will ask you to have the scan repeated in order to confirm the result.

Q. What are the limitations of the monitoring?

A. The equipment detects all the radiation emitted from radioactivity in your body including from natural radioactivity that is a normal part of our diet, as well as background radiation that is present in the environment around you. These background sources do limit our ability to detect trace levels of radioactivity but such levels are too low to be of an exposure concern.

Q. How much will the test cost?

A. There is no cost if you choose to be monitored.

Q. Who pays for my follow-up test if my screening test is positive?

A. [For E600] If you are recommended for an additional screening, we will ask you to have a second procedure in another scanner at no cost to you.

Q. Will we have Tricare reject paying for this?

A.There are no bills or cost charged to you or your Tricare program if you choose to participate in this internal monitoring.

Q. Will the machine make a lot of noise?

A. No.

Q. Will I be alone, or will I be able to see my parent/spouse/etc.?

A. You will be able to see your parent, spouse or significant other during monitoring.

Q. Is this going to take pictures like an MRI or an ultrasound?

A. There are no pictures taken; it only detects radiation emanating from low levels of radioactivity in your body.

Q. Does the machine pose an invasion to privacy?

A. No. The equipment is not like an airport scanner. It does not produce an image.

Q. Does this procedure cause radiation exposure?

A. No, the scanner only detects radiation. It does not transmit anything.

Q. Will this hurt?

A. No. It is non-invasive and painless.

Q. What happens if I am pregnant? Will the monitoring harm my baby?

A. The scan will not harm you or your baby.

Q. What happens if I move or change position during the monitoring? Will I have to restart the screening?

A. We encourage you to remain as still as possible for an accurate monitoring procedure.

Q. My child can be still if I'm holding him/her. Can we just both be scanned at the same time?

A. Each person will need to be scanned individually for the most accurate result. You may be asked to hold your child while he/she is being scanned. You will still need to be scanned individually.

Q. Do I need to remove my clothing during the screening?

A. The scan is performed in your normal clothing. We will ask you to remove only outer garments (coats or sweaters) and jewelry around your neck.

Q. Can I talk during the screening?

A. We encourage each person to remain as still as possible, to include talking to ensure accurate results.

Q. What happens if I sneeze or cough during the monitoring?

A. Don’t worry about sneezing or coughing. We only ask that you minimize your movements during the scan, approximately 10 [or 20 if using Accuscan] minutes.

Q. Does the machine need to touch my skin?

A. No.

Q. Is this a confined space like an MRI?

A. For Accuscan/Fastscan – the unit is open on the side so there is unimpeded access/egress.

Q. Do I need to use the restroom before the monitoring?

A. You can, but it is not required. We only ask that you remain still for approximately 10 [or 20 if using Accuscan] minutes required for monitoring.

Q. How do I find out the results?

A. A summary of the preliminary results will be discussed with you when the scan is complete. All scan results then go to the Naval Dosimetry Center for quality control and verification.

Q. Will the results be placed in my medical record?

A. The scan results will be maintained at the Naval Dosimetry Center in Bethesda, MD and available for entry into medical records.

Q. Do I get a handout with the results today after the monitoring? How about after the final review?

A. No, there will not be a handout to take with you at this time. A verbal summary will be provided

Q. For AD personnel, will the VA have these results when I retire?

A. Yes.

Q. My AD husband (or wife) was monitored—do I need to be monitored?

A. At this time we are offering the opportunity for internal monitoring if you choose to participate. There is no recommendation for you to be scanned simply because your spouse was previously scanned.

Q. My AD husband (or wife) was monitored, can I be exposed by the contamination detected in his/her internal monitoring.

A. Based on the many internal monitoring results that we have reviewed, we are confident that no significant internal radioactivity levels will be found. This of course will be confirmed with your monitoring results. Therefore, any radiation exposures you may get from your spouse will be insignificant.

Q. I left Japan during the evacuation, will my exposure be decreased? Do I need to be monitored?

A. Since you left the area, you were possibly exposed to radiation from the Fukushima Daiichi power plant for less time than had you stayed. The opportunity to participate in the internal monitoring scan is your choice whether you took part in the voluntary departure or if you stayed in Japan.

Q. Will it hurt my future VA benefits or ability to get health insurance if I get internal monitoring?

A. No, internal monitoring results will not affect future VA benefits or the ability to acquire health insurance.

Q. How long will internal monitoring be available? If the plant keeps leaking radiation, can we get tested again?

A. We are offering internal monitoring to the DOD affiliated population until XX Aug 2011. We continue to monitor the Fukushima Daiichi power plant status and will reassess availability as necessary.

Q. What effect would internal contamination have on a nursing mother and child?

A. The levels of exposure to U.S. citizens as a result of this event should have no impact on pregnancies. A physician or medical treatment provider should be able to discuss any potential impacts on nursing mothers and children. For additional information you can find information about radiation and pregnancy on the CDC webpage. http://www.bt.cdc.gov/radiation/

Q. Will I get cancer?

A. Exposure to low levels of radiation or radioactivity does not mean you will get cancer. There are many causes of cancer, both environmental and genetic. Radiation, specifically radiation at these levels, is a negligible contributor to your overall cancer risk. Cancer concerns should be discussed with a health care provider.

Q. Where can we find out additional information regarding internal contamination?

A. Additional information can be obtained from your medical treatment provider or from the Centers for Disease Control and Prevention (CDC) at http://www.bt.cdc.gov/radiation/

Abbreviations, Acronyms, and Unit Symbols

AB	Air Base
Act	Activity
AD	Active Duty
AMAD	Activity median aerodynamic diameter
AS	Submarine tender
Bkg	Background count rate
Bq	becquerel (SI unit of radioactivity)
BUMED	U.S. Navy Bureau of Medicine and Surgery
CD	Compact Disc
CDR	Commander (U.S. Navy)
CDE	Committed Dose Equivalent
CEDE	Committed Effective Dose Equivalent
CG	Cruiser, Guided Missile
Ci	curie (traditional unit of radioactivity)
Cnts	Counts
CONUS	Continental United States
cpm	counts per minute
CPT	Captain (U.S. Army)
CTBTO	Comprehensive Test Ban Treaty Organization
CV	Coefficient of variation
CVN	Aircraft Carrier, Nuclear-powered
d	day
DARWG	Dose Assessment and Recording Working Group
DC	Dose coefficient
DDG	Destroyer, Guided Missile
DOD	Department of Defense
DOEHS	Deployment Occupational & Environmental Health Surveillance
DTRA	Defense Threat Reduction Agency
Eff	Efficiency
FAC	Free-in-Air Condition
FDNPS	Fukushima Daiichi Nuclear Power Station
GOJ	Government of Japan
Gy	gray (SI unit of absorbed dose)
HM1	Hospital Corpsman First Class (U.S. Navy)
HPD	Health Physicist Directive
IADCT	Internal Activity and Dose Calculation Tool
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IM	internal monitoring
IMF	Intermediate Maintenance Facility
IMS	International Monitoring Station
IRF	Intake Retention Fraction
JSF-J	Joint Support Forces – Japan

KAPL	Knolls Atomic Power Laboratory
kBq	kilobecquerel
keV	kiloelectron volt
LCC	Amphibious Command Ship
LCDR	Lieutenant Commander (U.S. Navy)
LGI	Lower gastrointestinal tract
LHD	Multi-Purpose Amphibious Assault Ship
LSD	Landing Ship, Dock
LT	Lieutenant (U.S. Navy)
MCAS	Marine Corps Air Station
MDA	minimum detectable activity
MEC	Marine Expeditionary Camp
MeV	megaelectron volt
µg	microgram
µm	micrometer
mg	milligram
mrem	millirem
mSv	millisievert
NAF	Naval Air Facility
NAS	Naval Air Station
NB	Naval Base
nCi	nanocurie
ng	nanogram
NCRP	National Council on Radiation Protection and Measurements
n.d.	No date
NDC	Naval Dosimetry Center
NNPP	Naval Nuclear Propulsion Program
OCONUS	outside of the continental United States
OPNAV	Office of the Chief of Naval Operations
OT	Operation Tomodachi
pCi	picocurie
pg	picogram
PEP	potentially exposed population
PSNS	Puget Sound Naval Shipyard
QA	Quality Assurance
RADM	Rear Admiral (Upper Half) (U.S. Navy)
rem	roentgen equivalent man (traditional unit of dose equivalent)
RIMIS	Radiation Internal Monitoring by In Vivo Scanning
SAIC	Science Applications International Corporation
SFC	Sergeant First Class (U.S. Army)
SI	International System of Units
SM	Site Manager
SSG	Staff Sergeant (U.S. Army)
Sv	sievert (SI unit of dose equivalent)
T-AOE	Fast Combat Support Ship
TED	Total effective dose

TEPCO	Tokyo Electric and Power Company
Th	Thyroid
Thy	Thyroid
UGI	Upper gastrointestinal tract
URT	Upper respiratory tract
U.S.	United States
USPACOM	United States Pacific Command
WB	Whole body